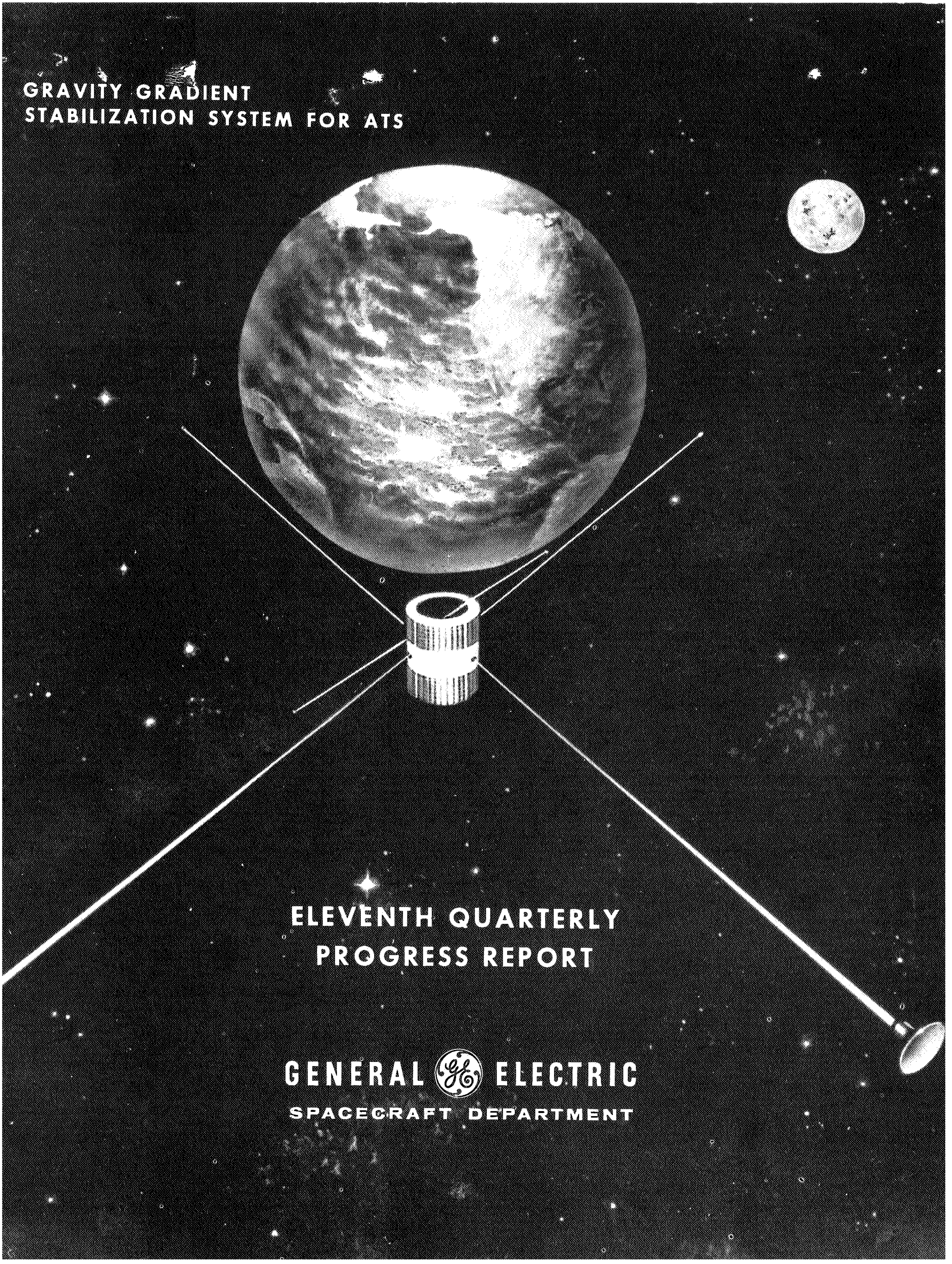
GRAVITY GRADIENT STABILIZATION SYSTEM FOR ATS



ELEVENTH QUARTERLY PROGRESS REPORT

GENERAL ELECTRIC

SPACECRAFT DEPARTMENT

DOCUMENT NO. 67SD4292
20 MAY 1967

ELEVENTH QUARTERLY PROGRESS REPORT
FOR THE
APPLICATIONS TECHNOLOGY SATELLITE
GRAVITY GRADIENT
STABILIZATION SYSTEM

1 FEBRUARY 1967 THROUGH 30 APRIL 1967

CONTRACT NO. NAS 5-9042

FOR THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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ABSTRACT

This reporting period includes ATS-A (ATS-2) launch from Cape Kennedy at 10:23 p. m. (EST) on 5 April 1967 on an Atlas/Agena D launch vehicle. Because of an improper Agena D second burn, the spacecraft was not placed into its planned 6000 nm circular orbit, but remained in a highly eccentric transfer orbit (6000 nm apogee by 100 nm perigee) after separation from the Agena. The gravity gradient boom system was successfully deployed on command and was verified by telemetry and TV camera system data. All other gravity gradient stabilization system components performed nominally.

Flight analysis activities, initially published in the Four-Day Report (GE Document No. 67SD4276) have been updated through the end of April and published in Section 2. System performance is presented with a consideration of the highly eccentric orbit, and a detailed performance analysis of each of the gravity gradient system components is given which is based on observed data.

Based on attitude sensor data obtained from the first 14 days of flight, the spacecraft appears to be continually tumbling, the highest tumbling rate was observed as 26.5 degrees per minute. In several instances, the attitude sensor data indicated a yaw inversion.

The flight of ATS-A in a nominal orbit would be expected to produce almost negligible dynamic motion of the gravity gradient booms. However, the orbit that was achieved produced noticeable flexible boom motions, as would be expected. An investigation of these boom dynamics in the highly elliptical orbit is presented in Section 2.4.

As outlined in the last quarterly report, Flight Unit Serial No. 10 Primary Boom failed to retract following thermal-vacuum exposure due to excessive loading during testing.

Leaks discovered during testing of the Flight Unit S/N **103** Primary Boom was found to have occurred at the enclosure/bellcrank housing interface weld. Improved manufacturing and leak testing techniques initiated during rework of the unit will be used on all subsequent units to ensure that this failure does not reoccur.

Results of tests involving the engineering unit damper boom to ensure that the spacecraft opening was sufficient to allow proper damper boom tip mass deployment in orbit was confirmed with the successful deployment of the ATS-A flight damper boom. However, a more pronounced rotation of the tip masses found to be inherent in the ATS-D/E damper booms will require an increase in the size of the spacecraft opening.

All tests of the Prototype No. 2 CPD and boom systems were completed. No degradation was observed as the result of the environments encountered during the spacecraft qualification tests.

The proposal submitted by GE to change the hysteresis damping torque of the Passive Hysteresis Damper from a constant to a varying function was accepted by NASA/GSFC. This change will be incorporated into the CPD units designated for the ATS-D/E. The effort includes the design, development, fabrication and testing. The engineering unit CPD has been reworked to the variable torque configuration, and has been successfully subjected to functional and qualification level vibration tests.

Loss of video during acceptance testing of the flight unit TV camera (S/N 5109), as reported in the Tenth Quarterly Report, was traced to the failure of two video output transistors. Following successful acceptance re-test, the camera was placed in bonded storage at GE.

During the last reporting period, the ATS-E Solar Aspect Sensor was returned to the vendor for repair of an intermittent connection. Upon return **of** the unit to GE, it was acceptance tested and placed in bonded storage at GE.

Emphasis in the area of ground testing was directed at the testing activities which took place at HAC, NASA/Goddard, and Cape Kennedy toward the launch of the ATS-A spacecraft.

SECTION 1

INTRODUCTION

1.1 PURPOSE

This report documents the technical progress made during the period from 1 February to 30 April 1967 toward the design and development of Gravity Gradient Stabilization Systems for the Applications Technology Satellites.

1.2 PROGRAM CONTRACT SCOPE

Under Contract NAS 5-9042, the Spacecraft Department of the General Electric Company has been contracted to provide Gravity Gradient Stabilization Systems for three Applications Technology Satellites: one to be orbited at 6000 nautical miles (ATS-A), and two to be orbited at synchronous altitude (ATS-D and ATS-E). Each system consists of primary booms, damper boom, damper, attitude sensors and the power conditioning unit. In addition to the flight systems, GE provided a thermal model, a dynamic model, an engineering unit and two prototype units. Two sets of aerospace ground equipment were also furnished by GE.

1.3 ATS-A LAUNCH SUMMARY

Flight acceptance of the ATS-A gravity gradient stabilization system was completed during the reporting period and the system was installed on the spacecraft. On 5 April 1967, the ATS-A was placed into a highly elliptical orbit. The gravity gradient system was deployed at first apogee (6000 nm) and all hardware provided by GE functioned without a single anomaly. The primary booms extended the full length as expected; the damper boom and CPD were uncaged and functioned properly. Both TV cameras were turned on and spectacular pictures of the earth and the gravity gradient rods were returned. Analysis of available data is reported in Section 2 of this report in addition to the "Four-Day Flight Report", GE Document No. 67SD4276.

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SECTION 2

SYSTEMS ANALYSIS AND INTEGRATION

2.1 EVENT SUMMARY

Events of significance to systems analysis and integration activities during the months covered by this reporting period are summarized as follows:

28 February	Simulated GE-POLANG data tape, for use in GE Data System Checkout, was received from NASA/GSFC.
1 March	Simulated NADT provided NASA/GSFC by GE for use in checkout of GSFC software.
1 March	Simulated GE Special Message provided NASA/GSFC in paper tape format for use in operations rehearsals.
2-3 March	First full-scale NASA launch rehearsal for ATS-A; GE was unable to participate due to delinquencies in establishment of NASCOM interface between GSFC and GE.
3 March	GE/NASA TTY link for quick-look service was completed through installation of NASCOM terminal equipment at GE.
3 March	The results of analytical and experimental investigations of the thermal bending behavior of overlapped gravity gradient rods was documented as Doc. No. 67SD4239 "Thermal Bending of deHavilland Type Rods."
6 March	Publication of "ATS-A Flight Evaluation Plan," Volume III of the Gravity Gradient Orbit Test Plan.

6 March	Equations for correction of "raw" POLANG data for use in GE's Quick-Look Attitude Determination Program were published in ATS Systems Memo No. 109; these equations were provided by R. Chaplick of GSFC and represent corrections necessary to account for ground station antenna-mount coordinates.
6 March	ATS Systems Memo No. 110 published summarizing recent data interface agreements between GSFC and GE; GE data tapes (RTDT and GE-POLANG) will be produced at GSFC on Tuesdays; GE will process these tapes and produce an NADT on Wednesdays; GSFC will process the NADT in conjunction with ATS ephemeris data to produce a tape for experimenters each Thursday. The method of transporting tapes between GSFC and GE remains unresolved. Justification of ATS Math Model Assumptions," was published.
10 March	Checkout of GE Data System using 3-file simulated steady-state RTDT was completed, This simulated tape was produced with the GE Data Simulation Program working with an output tape from the ATS Mathematical Model.
13-14 March	GE participated in an operational checkout of the quick-look data system with Rosman and Mojave ground stations.
14 March	ATS Systems Memo No. 112, "Comments on NASA Plans for ATS-A Launch Sequence" dated 9 March 1967 was published with updated handwritten comments as of 14 March.
15 March	"Geomagnetic Field Simulation for the ATS", Document No. 66SD4567, was published.

15 March	The Orbit Test Handbook was published as Appendix B Volume V, of the Gravity Gradient Orbit Test Plan.
15 March	Revision B, ATS Data Formats Specification, SVS-7429.
20 March	"DSCS Quick-Look Math Model," PIR 5540-48 was published. This contains the mathematics of GE's quick-look attitude determination programs.
21 March	ATS Systems Memos No. 113A and B (15 March and 21 March, respectively) contain final data on ATS-A Met tape recorder momentum vector, final spacecraft moments of inertia, results of GSFC magnetic dipole measurements, and a final assessment of spacecraft surface properties.
21-22 March	GE participated in a full-scale ATS-A launch rehearsal with E. Metzger, GSFC Operations Manager, in attendance at GE. GE successfully demonstrated a 15 minute turnaround time on the handling of the GE Special Message received from ATS ground stations via NASCOM and the established teletype network between GSFC and GE. A detailed critique on the rehearsal is contained in ATS Systems Memo No. 114.
27 March	Drawing No. 47C207338 was updated to portray final ATS-A flight configuration parameters.
27 March	"ATS-A Mission Description" published as Document No. 67SD4268.

28-29 March	GE participated in an ATS launch simulation exercise and successfully demonstrated readiness for flight.
31 March	Basic data system checkout of all GE software completed.
31 March	ATS-A Math Model capture studies indicate upright capture is feasible for "worst-case" Agena separation rates if the initial pointing angle (at time of boom deployment) is less than 40 degrees.
4-7 April	GE participated, in an advisory capacity, during launch and preliminary flight operations at NASA/GSFC and Cape Kennedy.
5 April	ATS-A was launched into a highly elliptical (e = 0.45574) orbit when Agena second burn failed to circularize the orbit at apogee. All gravity gradient hardware performed according to plan but the spacecraft went rapidly into a pitch tumbling mode due to the large orbit eccentricity.
10 April	"ATS-A Four-Day Flight Report" for the Applications Technology Satellite Gravity Gradient Stabilization System, Document No. 67SD4276; this report was based primarily on early RTDT and GE-POLANG tapes derived from ATS-2 data recorded at NASA/GSFC and received by GE on 7 and 10 April respectively. The report covers the first 2-1/2 days of the ATS-2 orbit. The GE data reduction programs had to be modified to account for IR sensor calibration changes resulting from the high-eccentricity orbit.
14 April	GE presentation of preliminary flight analysis results to NASA/GSFC ATS project management.

19 April	First processed tapes from the ATS ground stations received by GE; due to excessive overlap of time periods between ground stations, a substantial amount of data was lost in the first pass through GE data reduction programs. To recover this data, a portion of the GE attitude determination program had to be rewritten. The resultant NADT contained only 4 complete, 3-axis attitude data points due to the absence of sufficient 3-axis sensor data for determination of attitude at specified 5- minute intervals. The RTDT plots represent the primary source of data for flight analysis activities. Spacecraft tumbling rates of 12 to 30 degrees per minute are clearly evident in addition to the interplay between central body motion and boom dynamics resulting from eccentric orbit and tumbling dynamics excitations.
24 April	GE presentation to Dr. Clark and staff at NASA/GSFC; presentation included a summary of performance of ATS-2 as well as recommendation on continued experimentation with ATS-2 and the possibility of flight of the ATS-A prototype.
26 April	The second set of data tapes, containing 117 files of data. was received from NASA/GSFC. These tapes contained all data through 19 April including a repeat of all data on tapes received 19 April. Data was computed at 3-second intervals and an attempt at attitude computation using only one-axis IR sensor data was made. These efforts produced little additional information of significance, however. A primary source of uncertainty in all computations to date is the unexpected nature of the IR sensor calibration curve.

28 April	A summary critique on TV film data was prepared; 11 rolls of film, containing 2108 frames of "data" were received through 25 April. Only 238 frames contained data that was even partially interpretable. The absence of time codes and/or TV reticle marks, plus very poor quality of reproduction rendered the majority of the data unusable.
1 May	Three additional rolls of TV film were received from NASA/GSFC. The absence of a time code rendered the data unusable.
3 May	The third set of data tapes, containing 26 files of data, were received from NASA/GSFC at approximately 10:00 p. m.
4 May	Processing of data tapes began at 8:00 a.m. In lieu of an **NADT.** GE produced a **NASA** Sun Tape which contains direction cosines of the sun in body coordinates. This tape was in shipment to GSFC within 8 hours.
4 May	Three additional rolls of TV film were received from NASA; these films contain a very useful time code and can possibly lead to the generation of useful data for attitude determination, as well as correlation with IR sensor data. Quality of the film is still very poor, however, and very little of the TV reticle is visible - this severely limits the data utility and prevents checkout of the TV data reduction program. The prime objective (boom deflection data) cannot be accomplished without the reticle marks.
4 May	GE participated in IR sensor component tests at NASA/GSFC; the suspected "shift" in the space reading output was confirmed - a combination of telemetry data analysis and testing will hopefully produce a new calibration curve for the sensor which can be programmed into the GE Data Analysis Module of the Attitude Determination Program.

5 May	Examination of all GE Special Messages received to date was completed; usable messages were processed through GE's quick-look attitude determination programs for a final checkout of the quick-look system operational status. All but a very few of the **317** messages received were unusable due to questionable POLANG data or absence of 2-axis earth sensor data.

2.2 FLIGHT ANALYSIS

2.2.1 INTRODUCTION

Flight analysis activities, during the portion of this reporting period preceding launch, were concerned primarily with completion and publication of the Flight Evaluation Plan (Volume III of the Gravity Gradient Orbit Test Plan) and the Orbit Test Handbook (Appendix B, Volume V, of the Orbit Test Plan). In addition, final preparations for flight included participation in launch rehearsals and simulation exercises, as well as final data system checkout of all GE software.

The first two days of ATS-2 flight were documented in the "ATS-A Four-Day Flight Report," Document No. 67SD4276, dated 10 April 1967. The material in the following subsections includes the bulk of material contained in that four-day report, plus updates to include spacecraft activities and performance through 19 April 1967, the fourteenth day of flight. Analysis of data continues with emphasis being placed on an examination of "raw" data available from plots of RTDT tapes received from NASA/GSFC.

2.2.2 FLIGHT PROFILE SUMMARY

The ATS-2 spacecraft was launched from the Eastern Test Range at 03:23:02 GMT on 6 April 1967 aboard an Atlas SLV-3/Agena D launch vehicle. Due to an improper Agena D second burn, the spacecraft was not placed into its planned 6000 nm circular orbit, but remained in a highly eccentric (0.455) transfer orbit after separation from the Agena, at 05:23:43 GMT. Based on a NASA/GSFC orbit analysis estimate, a 0.008 per month decrease in orbit eccentricity is expected due to aerodynamic drag at perigee. Initial flight orbit characteristics are presented in Table 2-1.

Following spacecraft/booster separation, a nominal gravity gradient system deployment sequence was initiated, and completed without problem at 05:42:58 GMT, under control of ATSOCC at Goddard Space Flight Center and operated through the Toowoomba, Australia ground station. Proper deployment of the four primary gravity gradient system booms was verified by telemetry, and confirmed by later visual inspection of received video from the Television Camera Systems. The Solar Aspect Sensor and Damper Boom Angle Indicator were commanded On prior to boom deployment; Earth Sensors No. 1 and No. 2 were in operation throughout powered flight.

Both Earth Sensors No. 1 and No. 2, and Television Camera System No. 1 remained in operation for approximately 30 minutes following separation. Earth Sensor No. 2 was Commanded Off by the Toowoomba station at 05:52:44 GMT, in accordance with the nominal ATS-2 flight plan. Television Camera System No. 1 was commanded Off at 06:32:06 GMT.

At 19:25:30 GMT, Earth Sensor No. 2 was commanded On by the ground station in response to indications (Solar Aspect Sensor, Earth Sensor No. 1 data) of a vehicle attitude tumble condition.

After confirmation of the flight orbit achieved, spacecraft operation plans were adjusted to take into account the altitude, velocity, and station coverage range variations encountered.

Table 2-1. Flight Orbit

Parameter	Planned	Actual
Apogee	11107.04 km	11180.56 km
Perigee	11106.02 km	186.37 km
Inclination	28.35	28.32 deg
Eccentricity	0.005	0.455
Period	383.48 min	219.72 min

During the 14 days following gravity gradient initial system deployment, gravity gradient command activity was limited to turning on and off the various attitude sensors. A summary of all gravity gradient commands generated during the first 14 days of flight is presented in Table 2-2.

Ɔay	Item	Command Sent	T/M Verified
ⅼ/6	Liftoff	96/12181.9	---
	separation	96/19423.8	---
	PPS C ON	96/19455.0	96/19456.3
	Flre Boom A Sq. 1	96/19501.0	---
	Fire Boom B Sq. 1	96/19531.0	---
	Fire Boom A Sq. 2	96/19546.0	---
	Flre Boom B Sq. 2	96/19567.0	---
	TVCS No. 1 ON	96/19584.0	96/19586.8
	SAS/AI Cmd. B	96/19620.0	96/19637.2
	SAS/AI Cmd. C	96/19638.0	
	Motor A/B Ext.	96/19724.0	96/19895.2
	Flre Damper Boom Sq. A	96/19911.0	
	Flre Damper Boom Sq. A	96/19970.0	96/19984.2
	Flre Damper Boom Sq. B	96/19986.0	
	Fire Damper Sq. A	96/20372.0	96/20553.7
	Flre Damper Sq. B	96/20402.0	
	PPC C OFF	96/20581.0*	96/20580.4
	IR 2 OFF	96/21166.0	96/21167.0
	TVCS 1 OFF	96/23526.0	96/23528.6
	IR 2 ON	96/69930.0	96/69930.0**
	TVCS 1 ON	96/74576.0	96/74578.9
	TVCS 1 OFF	96/74926.0	96/74928.9
	TVCS 2 ON	96/74944.0	96/74946.7
	TVCS 2 OFF	96/75110.0	96/75112.8
/7	IR Earth sensor 1 OFF	97/68788	68788.2
	IR Earth Sensor 2 OFF	68803	68803.0
	IR Sensor 1 ON	74945	74945.7
	IR Sensor 2 ON	74975	74975.4
/8	TVCS Sys. 1 ON	98/ 385	385.7
	TVCS Sys. 1 OFF	480	480.6
	TVCS Sys. 1 ON	2310	2310.8
	TVCS Sys. 1 OFF	3900	---
	TVCS Sys. 1 OFF	3955	39561.8
	TVCS Sys. 2 ON	5600	5600.1
	TVCS Svs. 2 OFF	6060	6062.8
	TVCS Sys. 1 ON	6155	6157.7
	TVCS Sys. 1 OFF	6390	6392.0
	TVCS Sys. 2 ON	6900	6902.2
	TVCS Sys. 2 OFF	7010	7011.9
	IR Earth Sensor 1 OFF	7530	7531.0
	IR Earth Sensor 2 OFF	7550	7551.7
	IR Earth Sensor 1 ON	14885	14886.6
	IR Earth Sensor 2 ON	14905	14907.4
	TVCS Svs. 2 ON	15550	15551.0
	TVCS Sys. 2 OFF	15960	15960.3
	TVCS Sys. 1 ON	16250	16250.8
	TVCS Sys. 1 OFF	16585	16586.2
	TVCS Sys. 2 ON	16750	16752.3
	TVCS Sys. 2 OFF	17330	17330.6
	TVCS Sys. 1 ON	17475	17476.0
	TVCS Sys. 1 OFF	17855	17855.6
	TVCS Sys. 2 ON	18060	18060.3
	TVCS Sys. 2 OFF	18490	18490.3
	TVCS Sys. 2 ON	19800	19801.3
	TVCS Sys. 2 OFF	20010	20011.9
	TVCS.Sys. 1 ON	20115	20115.7
	TVCS Sys. 1 OFF	20255	20255.1
	TVCS Sys. 2 ON	98/20275	20275.1
	TVCS Sys. 2 OFF	20470	20471.4
	TVCS Sys. 1 ON	20495	20498.1
	TVCS Sys. 1 OFF	20565	20566.3
	TVCS Sys. 2 ON	20685	20687.9
	TVCS Sys. 2 OFF	20775	20776.9
	IR Earth Sensor 1 OFF	21745	21746.8
	IR Earth Sensor 2 OFF	21765	21767.6
/9	SAS and Angle Det. C	99/59820	60151.0
	IR Sensor 1 ON	60020	60020.5
	IR Sensor 2 ON	60045	60047.2
	SAS and Angle Det. D	60150	60151.0
	All Sensors OFF	60575	Improper Command
	SAS and Angle Det. C	60690	60690.8
	SAS and Angle Det. D	60730	60732.4
	SAS and Angle Det. A	60910	60910.3
	SAS and Angle Det. D	60955	
	SAS and Angle Det. B	65700	65700.4
	SAS and Angle Det. D	65735	
	IR Sensor 1 OFF	65830	65830.9
	IR Sensor 2 OFF	65855	65857.6
	SAS and Angle Det. A	74495	74497.6
	SAS and Angle Det. D	74595	
	IR Sensor 1 ON	74660	74660.8
	IR Sensor 2 ON	74690	74690.4
	SAS and Angle Det. B	80350	80352.5
	SAS and Angle Det. D	80382	
	IR Sensor 1 OFF	80430	80432.6
	IR Sensor 2 OFF	80460	80462.3
	SAS and Angle Det. A	83410	83410.5
	SAS and Angle Det. D	83430	
	IR Sensor 1 ON	83485	83487.6
	IR Sensor 2 ON	83510	83511.3

Day	Item	Command Sent	T/M Verified
4/10	IR Sensor 1 OFF	100/ 5200	5200.0
	IR Sensor 2 OFF	5220	5223.4
	IR Sensor 1 ON	5665	5665.3
	IR Sensor 2 ON	5685	5686.1
	IR Sensor 1 OFF	7545	7545.E
	IR Sensor 2 OFF	7565	7566.5
	SAS and Angle Det. B	7580	7581.4
	SAS and Angle Det. D	7595	
	IR Sensor 1 ON	12175	12175.7
	IR Sensor 2 ON	12210	12211.3
	SAS and Angle Det. A	12235	12235.1
	SAS and Angle Det. D	12255	
	SAS and Angle Det. B	19720	19721.3
	SAS and Angle Det. D	19740	
	IR Sensor 1 OFF	19770	19771.7
	IR Sensor 2 OFF	19795	19795.4
	IR Sensor 1 ON	65370	66377***
	IR Sensor 2 ON	65395	66377***
	SAS and Angle Det. B	65425	66377***
	SAS and Angle Det. C	65450	66377***
	All Sensors OFF	67520	Improper Command
	IR Sensor 1 OFF	67630	67631.3
	IR Sensor 2 OFF	67650	67652.1
	TVCS 2 ON	70202	70202.9
	SAS and Angle Det. B	70753	Improper Command
	SAS and Angle Det. C	70764	
	TVCS 2 OFF	71422	71424.8
	All Sensors OFF	71437	Improper Command
	SAS and Angle Det. B	71708	71721.4
	SAS and Angle Det. D	71720	
	IR Sensor 1 ON	81270	81272.0
	IR Sensor 2 ON	81290	81292.8
	SAS and Angle Det. B	81320	---
	SAS and Angle Det. C	81340	
	SAS and Angle Det. B	82025	82052.1
	SAS and Angle Det. C	82050	
	IR Sensor 1 OFF	85689	85691.4
	IR Sensor 2 OFF	85703	85703.2
	SAS and Angle Det. B	85719	85729.9
	SAS and Angle Det. D	85730	
1/11	IR Sensor 1 ON	101/ 2865	2865.4
	IR Sensor 2 ON	2887	2889.1
	SAS and Angle Det. B	2907	2927.7
	SAS and Angle Det. C	2926	
	TVCS 1 ON	3993	3995.5
	IR Sensor 1 ON	4037	Improper Command
	IR Sensor 2 ON	4058	Improper Command
	TVCS 1 OFF	4210	4212.0
	TVCS 2 ON	4230	4232.8
	TVCS 2 OFF	4514	4514.5
	TVCS 1 ON	4538	4538.3
	TVCS 2 OFF	6617	Improper Command
	TVCS 1 OFF	6665	6665.0
	TVCS 1 ON	9098	9100.0
	TVCS 1 OFF	9928	9930.5
	TVCS 2 ON	9952	9954.2
	TVCS 2 OFF	10543	10544.4
	TVCS 1 ON	10570	10571.1
	IR Sensor 1 OFF	10718	10719.4
	IR Sensor 2 OFF	10740	10740.2
	SAS and Angle Det. B	10760	10781.7
	SAS and Angle Det. D	10780	
	TVCS 1 OFF	11142	11143.6
	IR Sensor 1 ON	18615	18615.0
	IR Sensor 2 ON	18645	18647.6
	SAS and Angle Det. B	18675	—
	SAS and Angle Det. C	18725	
	SAS and Angle Det. B	18790	18816.6
	SAS and Angle Det. C	18815	
	TVCS 1 ON	19195	19196.3
	SAS and Angle Det. B	24380	24423.4
	SAS and Angle Det. D	24420	
	IR Sensor 1 OFF	24460	24460.9
	IR Sensor 2 OFF	24480	24481.7
	IR Sensor 1 ON	67730	67732.2
	IR Sensor 2 ON	67770	67770.7
	SAS and Angle Det. B	67790	67830.1
	SAS and Angle Det. C	67830	
	IR Sensor 1 OFF	71505	71508.0
	IR Sensor 2 OFF	71528	71528.7
	SAS and Angle Det. C	71550	71564.3
	SAS and Angle Det. D	71564	
	IR Sensor 1 ON	72711	72712.2
	IR Sensor 2 ON	72730	72732.9
	SAS and Angle Det. B	72749	72768.5
	SAS and Angle Det. C	72767	
	IR Sensor 1 OFF	77527	No Data Available
	IR Sensor 2 OFF	77545	No Data Available
	SAS and Angle Det. B	77567	No Data Available
	SAS and Angle Det. D	77585	
	IR Sensor 1 ON	80590	80592.8
	IR Sensor 2 ON	80615	80616.6
	SAS and Angle Det. B	80640	80661.1
	SAS and Angle Det. C	80660	

Ɔay	Item	CO
ⅼ/11	TVCS 1 ON	1
	TVCS 1 OFF	
	TVCS 2 ON	
	TVCS 2 OFF	
	TVCS 1 ON	
	TVCS 1 OFF	
	TVCS 2 ON	
	TVCS 2 OFF	
	TVCS 1 ON	
1/12	TVCS 1 OFF	1
	TVCS 2 OFF	
	TVCS 2 ON	
	TVCS 2 OFF	
	TVCS 1 ON	
	TVCS 1 OFF	
	TVCS 2 ON	
	TVCS 2 OFF	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	TVCS 1 ON	
	IR Sensor 1 ON	
	IR Sensor 2 ON	
	IR sensor 1 OFF	
	IR Sensor 2 OFF	
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	TVCS 1 ON	
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	TVCS 2 OFF	
	TVCS 1 ON	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	TVCS 1 OFF	
	IR Sensor 1 ON	
	IR Sensor 1 ON	
	SAS and Angle Det. B	
	SAS and Angle Det. C	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	SAS and Angle Det. B	
	SAS and Angle Det. D	
	IR Sensor 1 ON	
	IR Sensor 2 ON	
	SAS and Angle Det. B ON	
	SAS and Angle Det. C ON	
	TBCS 2 ON	
	IR sensor 1 OFF	
	IR Sensor 2 OFF	
	TBCS 2 OFF	
	IR Sensor 1 ON	
	IR Sensor 2 ON	
/13	IR Earth Sensor 1 OFF	1
	IR Earth Sensor 2 OFF	
	IR Earth Sensor 1 ON	
	IR Earth Sensor 2 ON	
	TVCS 2 ON	
	TVCS 2 OFF	
	TVCS 1 ON	
	TVCS 2 ON	
	TVCS 1 OFF	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	TVCS 2 OFF	
	TVCS 2 ON	
	TVCS 2 OFF	
	IR Sensor 1 ON	
	IR Sensor 2 ON	
	SAS and Angle Det.	
	SAS and Angle Det.	
	TVCS 1 ON	
	TVCS 1 OFF	
	TVCS 2 ON	
	TBCS 2 OFF	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	SAS and Angle Det. B	
	SAS and Angle Det. D	
	IR Sensor 1 ON	
	SAS and Angle Det.	
	SAS and Angle Det.	
	IR Sensor 1 OFF	
	IR Sensor 2 OFF	
	SAS and Angle Det.	
	SAS and Angle Det.	
	IR Earth Sensor 1 ON	
	IR Earth Sensor 2 ON	
	SAS and Angle Det.	
	SAS and Angle Det.	
	IR Earth Sensor 1 OFF	
	IR Earth Sensor 2 OFF	
	IR Earth Sensor 1 ON	
	IR Earth Sensor 2 ON	

* Cmd. time given by NASA status report

...d Sent	T/M Verified
3177	82179.7
3460	83461.0
3480	83481.8
3765	83766.5
3785	83787.3
2440	84440.0
4465	84466.5
5335	85335.5
5355	85356.3
0	0.3
25	Improper Command
80	80.3
680	682.5
705	706.2
1495	1495.2
1515	1516.0
4568	4568.0
4587	4588.7
4602	4603.6
8520	No Data Available
8545	No Data Available
8565	No Data Available
6000	16002.0
6025	16025.7
6845	16847.3
6100	26101.3
6130	26131.0
6220	26220.0
6970	26970.3
7000	27000.0
8920	28922.0
8945	29945.7
9455	29455.8
9485	29485.5
9720	No Data Available
9745	No Data Available
9960	No Data Available
9035	No Data Available
9055	No Data Available
9090	No Data Available
9110	No Data Available
9849	No Data Available
9878	No Data Available
9959	No Data Available
9976	No Data Available
2504	No Data Available
2530	No Data Available
2553	No Data Available
2568	No Data Available
2415	82595.0
2730	82731.4
2750	82752.2
3055	83057.7
6130	86130.5
6170	86172.0
9515	9515.3
9535	9536.1
4670	14670.3
4695	14697.0
4775	14777.1
6765	14767.3
6785	16785.1
7215	17215.1
7245	17247.8
9860	19860.8
9880	19881.6
9905	19905.3
1795	21797.6
2130	22132.7
4113	64113.6
4129	64129.0
4146	Improper Command
4161	
6364	66364.9
6572	66572.5
6587	66587.3
6858	66860.2
7011	67011.5
7026	67026.3
7041	67053.0
7053	
2905	72907.9
2920	72931.1
2930	
3929	73931.1
3944	Improper Command
3958	73975.6
3973	
8590	78590.7
8610	78611.5
8685	78712.4
8710	
2525	82526.7
2550	82550.4
2580	82580.1
2600	82600.8

Day	Item	Command Sent	T/M Verified
1/14	IR Earth Sensor 1 OFF	104/ 1170	1171.8
	IR Earth Sensor 2 OFF	1190	1192.6
	IR Earth Sensor 1 ON	5260	5262.0
	IR Earth Sensor 2 ON	5280	5280.0
	IR Earth Sensor 1 OFF	14460	14462.5
	IR Earth Sensor 2 OFF	14480	14480.3
	TVCS 1 ON	17254	No Data Available
	IR Sensor 1 ON	21490	21492.0
	IR Sensor 2 ON	21515	21515.7
	TVCS 1 OFF	25480	25481.2
	TVCS 2 ON	25510	25510.9
	TVCS 2 OFF	26185	26187.1
	TVCS 1 ON	26210	26210.9
	TVCS 1 OFF	26450	26451.1
	TVCS 2 ON	26470	26471.9
	IR Sensor 1 OFF	27015	27017.6
	IR Sensor 2 OFF	27040	27041.3
	TVCS 2 OFF	27140	27142.2
	TVCS 1 OFF	73250	Improper Command
	TVCS 2 ON	78785	78786.4
	TVCS 2 OFF	79290	79290.6
	SAS and Angle Det. B	79330	79361.8
	SAS and Angle Det. D	79360	
	IR Earth Sensor 1 ON	82850	82864.7
	IR Earth Sensor 2 ON	82875	82876.5
	SAS and Angle Det. B	82900	82926.9
	SAS and Angle Det. C	82925	
1/15	IR Earth Sensor 1 OFF	105/ 6265	6267.3
	IR Earth Sensor 2 OFF	6300	6300.0
	IR Earth Sensor 1 ON	10915	10915.1
	IR Earth Sensor 2 ON	10935	10935.8
	IR Sensor 1 OFF	18810	18810.6
	IR Sensor 2 OFF	18830	18831.4
	IR Sensor 1 ON	60720	60720.3
	IR Sensor 2 ON	60740	60741.1
	IR Sensor 1 OFF	62430	62431.7
	IR Sensor 2 OFF	62455	62455.5
	IR Sensor 1 ON	74375	74375.8
	IR Sensor 2 ON	74405	74405.5
	IR Sensor 1 OFF	84560	84561.1
	IR Sensor 2 OFF	84585	84585.0
1/16	IR Earth Sensor 1 ON	106/ 1780	1782.6
	IR Earth Sensor 2 ON	1800	1800.4
	TVCS 1 ON	7285	7287.5
	TVCS 2 ON	8205	8207.0
	TVCS 1 OFF	8245	8245.6
	TVCS 1 ON	8870	8871.4
	TVCS 2 OFF	8890	8892.2
	TVCS 2 ON	9890	9891.7
	TVCS 1 OFF	9910	9912.5
	TVCS 1 ON	10075	10075.6
	TVCS 2 OFF	10095	10096.4
	TVCS 1 OFF	10240	10241.7
	IR Earth Sensor 1 OFF	10290	10292.1
	IR Earth Sensor 2 OFF	10310	10310 0
	IR Earth Sensor 1 ON	17020	17051.7
	IR Earth Sensor 2 ON	17065	17066.5
	TVCS 1 ON	22990	22992.5
	TVCS 1 OFF	23135	23137.9
	TVCS 2 ON	23160	23161.6
	TVCS 2 OFF	23495	23496.8
	TVCS 1 ON	23510	23511.6
	IR Sensor 1 OFF	23720	23722.2
	IR Sensor 2 OFF	23740	23740.0
	TVCS 1 OFF	23760	23760.7
	IR Sensor 1 ON	65745	65747.6
	IR Sensor 2 ON	65775	65777.2
	TVCS 1 ON	66945	66945.8
	TVCS 1 OFF	67270	67272.1
	TVCS 1 ON	68010	68010.7
	TVCS 1 OFF	68210	68212.3
	TVCS 1 ON	69055	69057.7
	TVCS 1 OFF	69115	69117.0
	TVCS 2 ON	69140	69140.0
	TVCS 2 OFF	69540	69541.1
	IR Sensor 1 OFF	74580	74580.4
	IR Sensor 2 OFF	74600	74601.1
	IR Earth Sensor 1 ON	79660	79661.1
	TVCS 2 OFF	79680	Improper Command
	IR Earth Sensor 2 ON	79765	79765.0
4/17	IR Earth Sensor 1 OFF	107/ 3400	3401.9
	IR Earth Sensor 2 OFF	3445	3446.4
	IR Earth Sensor 1 ON	7290	7290.4
	IR Earth Sensor 2 ON	7315	7317.1
	TVCS 1 ON	14585	No Data Available
	TVCS 1 OFF	15590	No Data Available
	IR Earth Sensor 1 OFF	16825	16826.1
	IR Earth Sensor 2 OFF	16840	16840.9
	IR Sensor 1 ON	24444	24445.8
	IR Sensor 2 ON	24467	24469.5
	TVCS 1 ON	27062	27064.8
	TVCS 1 OFF	27506	27506.7
	TVCS 2 ON	27525	27557.1
	TVCS 2 OFF	27874	No Data Available
	TVCS 1 ON	27894	No Data Available

Day	Item	Command Sent	T/M Verified
4/17	IR Sensor 1 OFF	107/28209	28209.6
	IR sensor 2 OFF	28227	28227.4
	TVCS 1 OFF	28245	28245.2
	IR Sensor 1 ON	72600	72601.9
	IR Sensor 2 ON	72630	72631.6
	TVCS 1 ON	78885	78886.9
	TVCS 1 OFF	79720	79720.4
	TVCS 2 ON	79740	79741.1
	TVCS 2 OFF	80745	80746.6
	IR Sensor 1 OFF	80800	80800.0
	IR Sensor 2 OFF	80825	80826.7
	IR Sensor 1 ON	85885	85886.7
	IR Sensor 2 ON	85910	86910.4
4/18	IR Earth Sensor 1 OFF	108/ 8595	No Data Available
	IR Earth Sensor 2 OFF	8610	No Data Available
	IR Earth Sensor 1 ON	13050	13050.3
	IR Earth Sensor 2 ON	13070	13071.0
	IR Earth Sensor 1 OFF	20205	20207.2
	IR Earth Sensor 2 OFF	20225	20225.0
	IR Sensor 1 ON	62250	62250.4
	IR Sensor 2 ON	62275	62277.1
	IR Sensor 1 OFF	64710	64712.2
	IR Sensor 2 OFF	64735	64735.9
	IR Earth Sensor 1 ON	80690	80690.1
	IR Earth Sensor 2 ON	80710	80710.9
	IR Earth Sensor 1 OFF	86310	86310.7
	IR Earth sensor 2 OFF	86335	8337.4
4/19	IR Earth Sensor 1 ON	109/ 3505	3505.5
	IR Earth Sensor 2 ON	3525	3526.3
	TVCS 1 ON	6835	6836.3
	TVCS 1 OFF	7905	7907.1
	TVCS 1 ON	8165	8168.1
	TVCS 1 OFF	8420	8420.2
	IR Earth Sensor 1 OFF	11800	11801.4
	IR Earth Sensor 2 OFF	11820	11822.2
	IR Earth Sensor 1 ON	19025	---
	IR Earth Sensor 1 ON	19085	19085.9
	IR Earth Sensor 2 ON	19115	19115.6
	TVCS 1 ON	23500	23502.3
	TVCS 1 OFF	23925	23926.5
	TVCS 2 ON	23945	23947.2
	TVCS 2 OFF	24725	24727.3
	TVCS 1 ON	24750	24751.0
	IR Earth Sensor 1 OFF	25030	25032.8
	IR Earth Sensor 2 OFF	25050	25050.6
	TVCS 1 OFF	25085	25086.2
	IR Sensor 1 ON	67075	67076.0
	IR Sensor 2 ON	67100	67102.7
	TVCS 1 ON	70725	70697.5
	TVCS 1 OFF	70790	70792.4
	TVCS 1 ON	70995	10997.1
	TVCS 1 OFF	71098	71100.9
	TVCS 2 ON	71120	71121.7
	TVCS 2 OFF	71375	71376.7
	TVCS 2 ON	75020	75021.9
	TVCS 2 OFF	75875	75876.1
	TVCS 1 ON	75995	75997.7
	TVCS 1 OFF	76305	76306.2
	TVCS 2 ON	76340	76341.8
	TVCS 2 OFF	76760	76763.0
	TVCS 1 ON	76780	76780.8
	TVCS 1 OFF	76980	76982.5
	IR Sensor 1 OFF	77700	---
	IR Sensor 2 OFF	77723	77724.0
	IR Sensor 1 ON	81295	Improper Command
	IR Sensor 2 ON	81315	81315.8
	TVCS 1 ON	81628	81630.2
	TVCS 1 OFF	83073	83074.7
	TVCS 2 ON	83093	83095.4
	TVCS 2 OFF	85112	85112.3
	TVCS 1 ON	85145	85145.0
	TVCS 1 OFF	86325	86325.4
	TVCS 2 ON	86340	86340.2

2.2.3 SYSTEM PERFORMANCE

The gravity gradient system has been prevented from establishing gravity-referenced stability by effects of the highly eccentric flight orbit. Large attitude excursions have been indicated by raw sensor data, and predicted by preliminary simulation of spacecraft performance under the existing flight conditions. Complete determination of attitude performance has been precluded by these widely varying excursions (and by the large variation in spacecraft altitude).

2.2.3.1 Indicated Attitude Performance

The status of spacecraft attitude sensors in the vicinity of spacecraft-Agena separation (19422 sec) was:

a. SAS OFF

b. IR No. 1 ON

c. IR No. 2 ON

d. TVCS No. 1 OFF

e. TVCS No. 2 OFF

The earth was in the field of view of IR Sensor No. 1 from data acquisition through spacecraft Agena separation. Based on the motion of the earth within the field of view of IR Sensor No. 1, the spacecraft was separated from the Agena with a pointing attitude rate of 0.33 degrees per second. The exact motion of the spacecraft (pitch vs roll) cannot be determined since the exact yaw attitude at separation is not known.

The earth left the field of view of IR No. 1 at 19,500 seconds (see Figure 2-1). At 19,638 seconds, the Solar Aspect Sensor was turned on for the first time. Based on Solar Aspect Sensor data, the spacecraft pointing angle (with respect to local vertical) continued to increase at the tip-off angular velocity until the primary booms were extended, at which time (19,724 seconds) a significant decrease in pointing angle rates is evident.

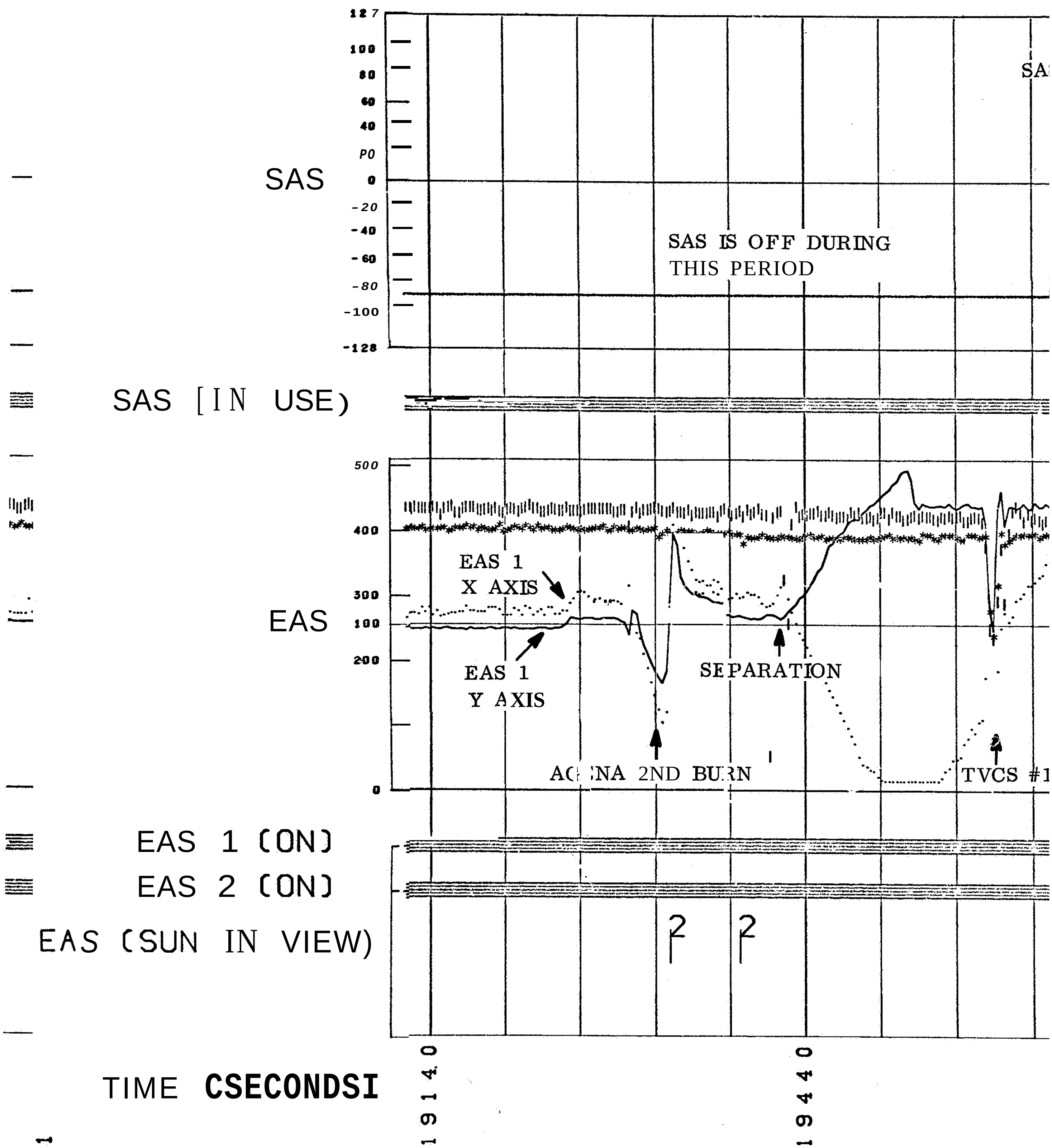
The earth returned into the field of view of IR Sensor No. 1 at approximately 22,000 seconds. For the first time, a two-sensor (earth and sun) solution of spacecraft attitude was possible. The computed attitude is shown in Figure 2-2. The same spacecraft attitude, expressed in terms of pointing angle is shown in Figure 2-3. The pointing angle in the vicinity of separation is also shown.

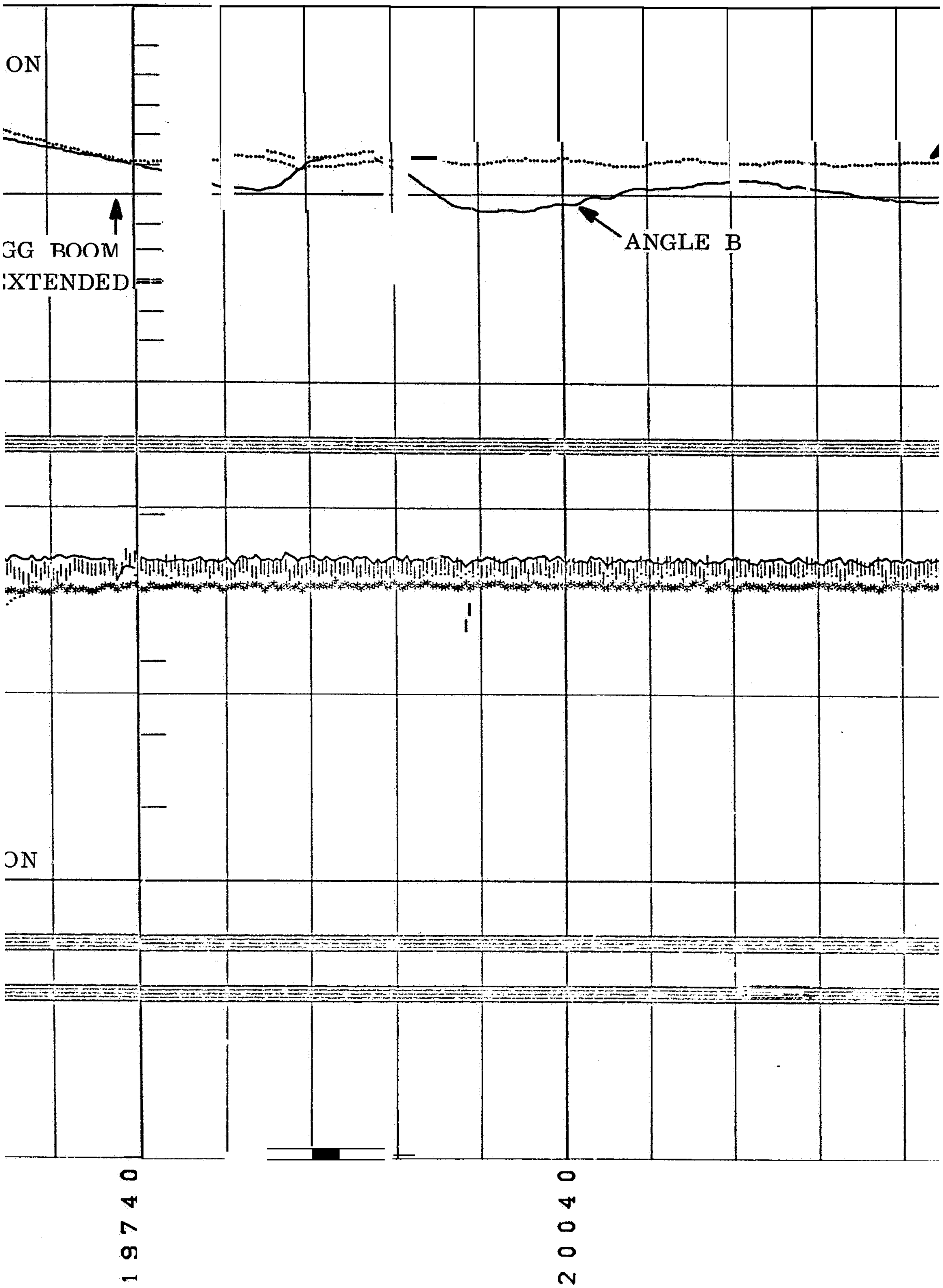
Based on attitude data shown in Figure **2-3** and Solar Aspect Sensor data in the interim period, it is apparent that the spacecraft did not invert on its initial swing. This is consistent with results of the mathematical simulations in the vicinity of the 1st apogee based on a "best" approximation to the initial conditions. No spacecraft data was obtained from 26,400 seconds (1st perigee) to 56,000 seconds (4th apogee). Solar Aspect Sensor data (Figure 2-4) in the vicinity of 56, 000 seconds clearly indicates that the spacecraft was in a tumble mode. This is evident from the cyclic switching of sun detectors located around the spacecraft belly-band. The order in which the sun detectors view the sun is 2, 4, 3, 2, 4, etc. The order, together with the detector angular outputs, shows the spacecraft to be rotating about its Z axis in the negative direction with small oscillations about the spacecraft Y axis. The rate of rotation about the Z axis is one revolution in 1 hour and four minutes, or 5.6 degrees per minute.

It should be emphasized that this pattern of motion can be achieved only in the presence of damping. The mathematical model indicates that in spite of the high rates of the spacecraft the damper will damp the motion. Damper boom motion observed from flight data supports the conclusion that the damper is free to rotate and is responding to vehicle dynamics. Switching to the hysteresis mode can verify proper action of the other damper.

Because of the absence of data between the first perigee and fourth apogee, it is impossible to estimate when the spacecraft tumbling began.

At 70,000 seconds the earth appeared in the field of view of IR Sensor No. 2, allowing a two-sensor attitude computation. The results are shown in Figure 2-5.


SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS IS OFF DURING
THIS PERIOD
SAS [IN USE)
EAS
500
400
300
100
200
0
EAS 1
X AXIS
EAS 1
Y AXIS
SEPARATION
AGENA 2ND BURN
TVCS #1
EAS 1 (ON)
EAS 2 (ON)
EAS (SUN IN VIEW)
2
2
TIME CSECONDSI
19140
19440


ON
GG BOOM
XTENDED
ANGLE B
ON
19740
20040

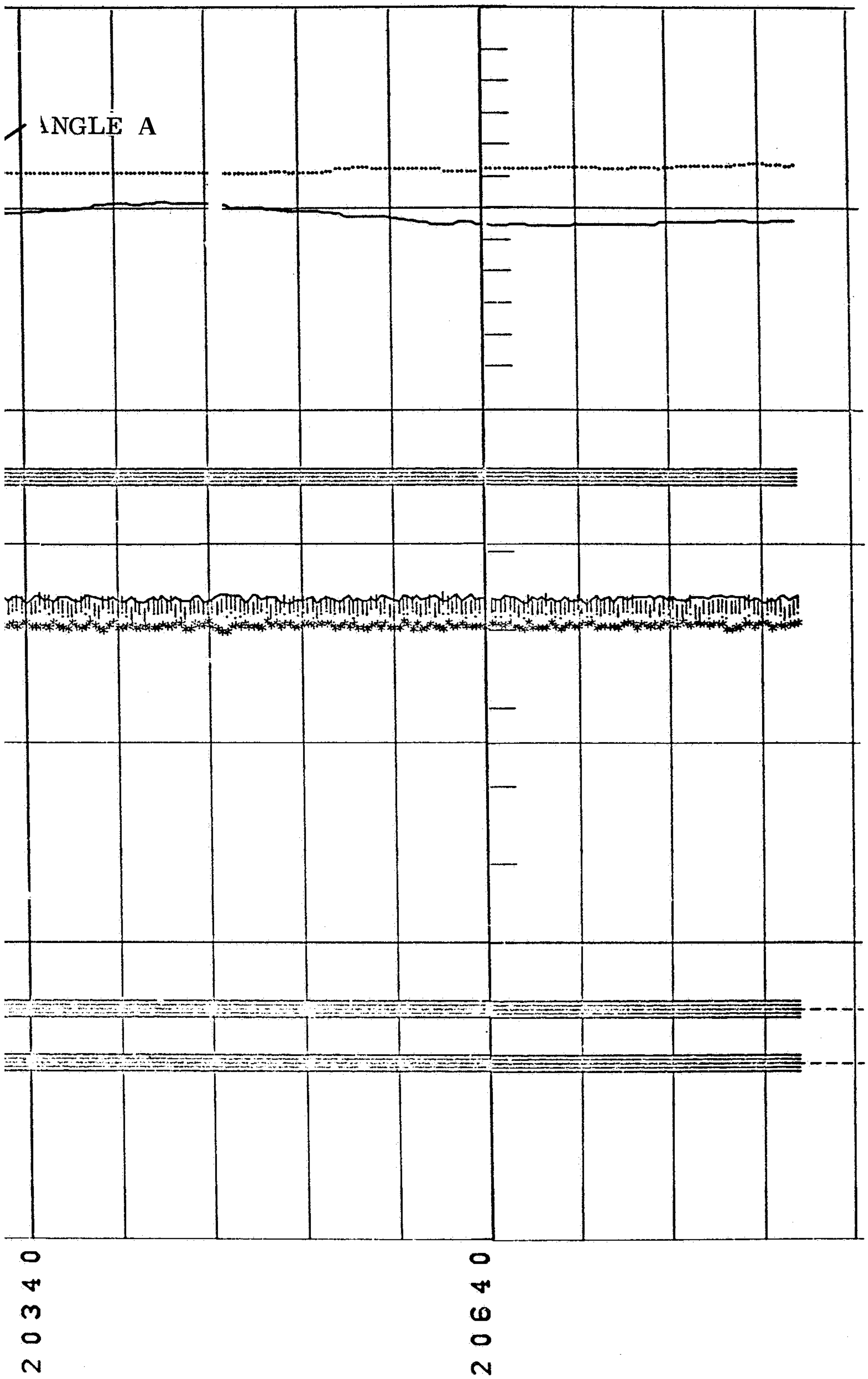


Figure 2-1. Attitude Sensor Data (1)- Day 96

2-16-2
[redacted]

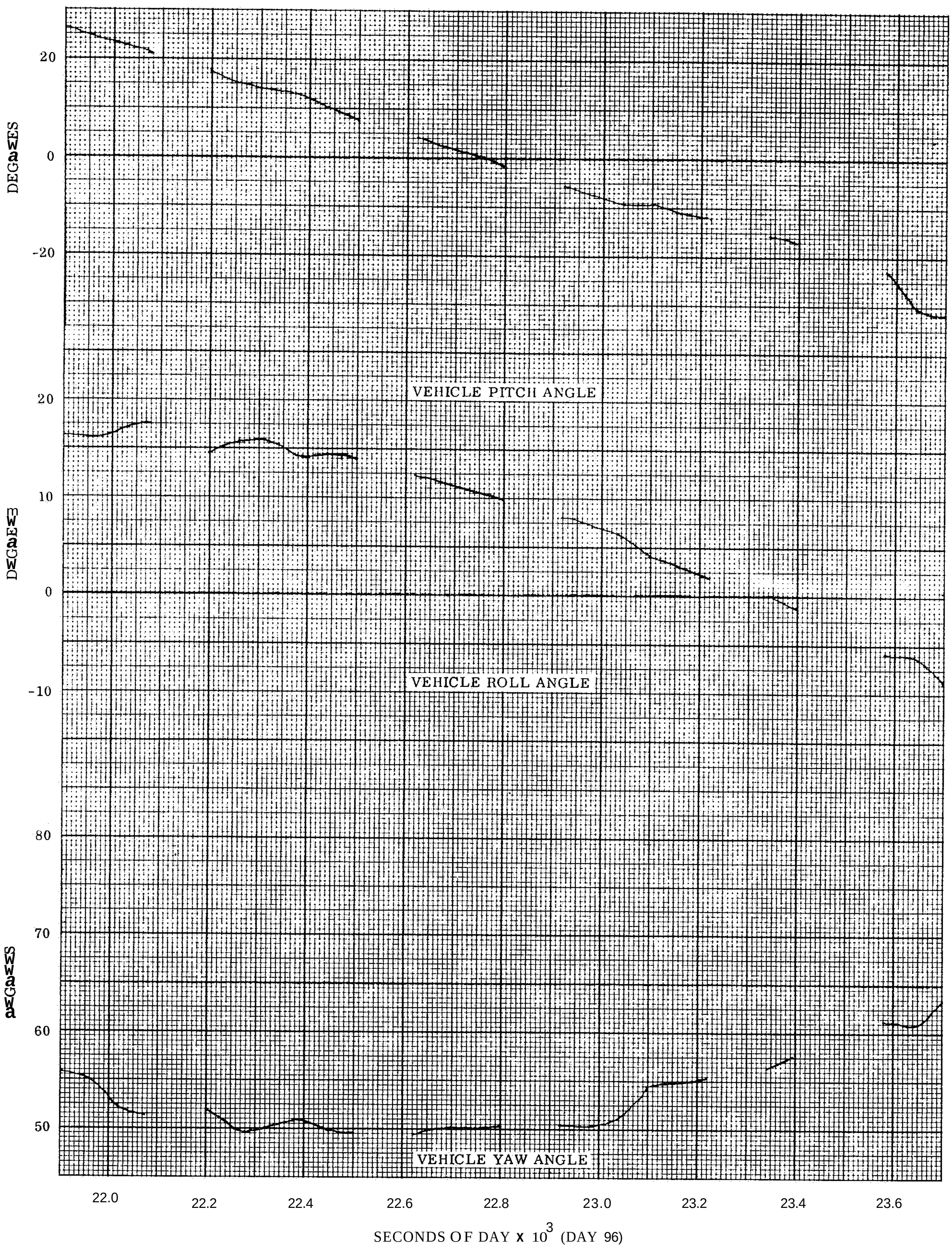


Figure 2-2. Computed Attitude (1)- Day 96

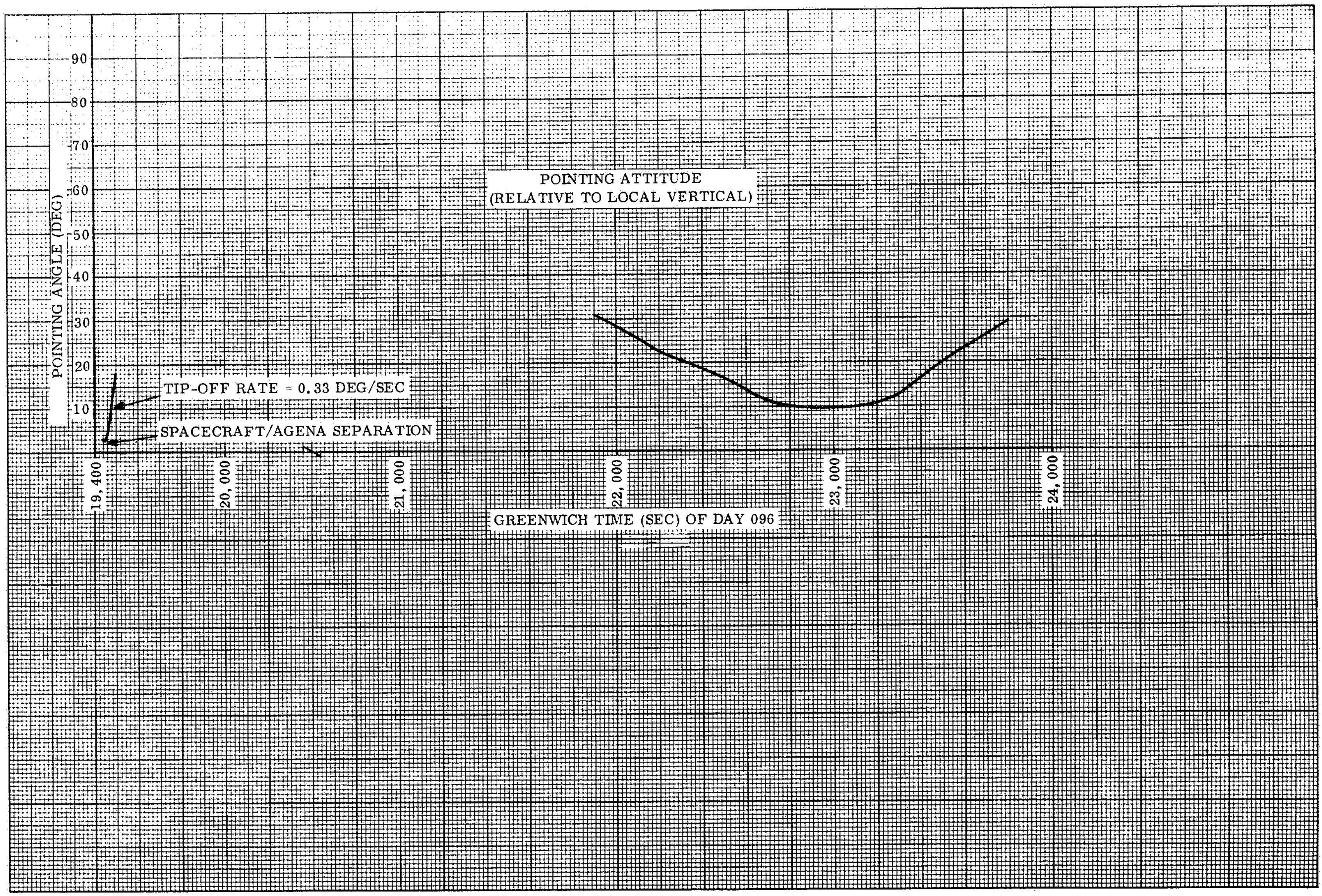
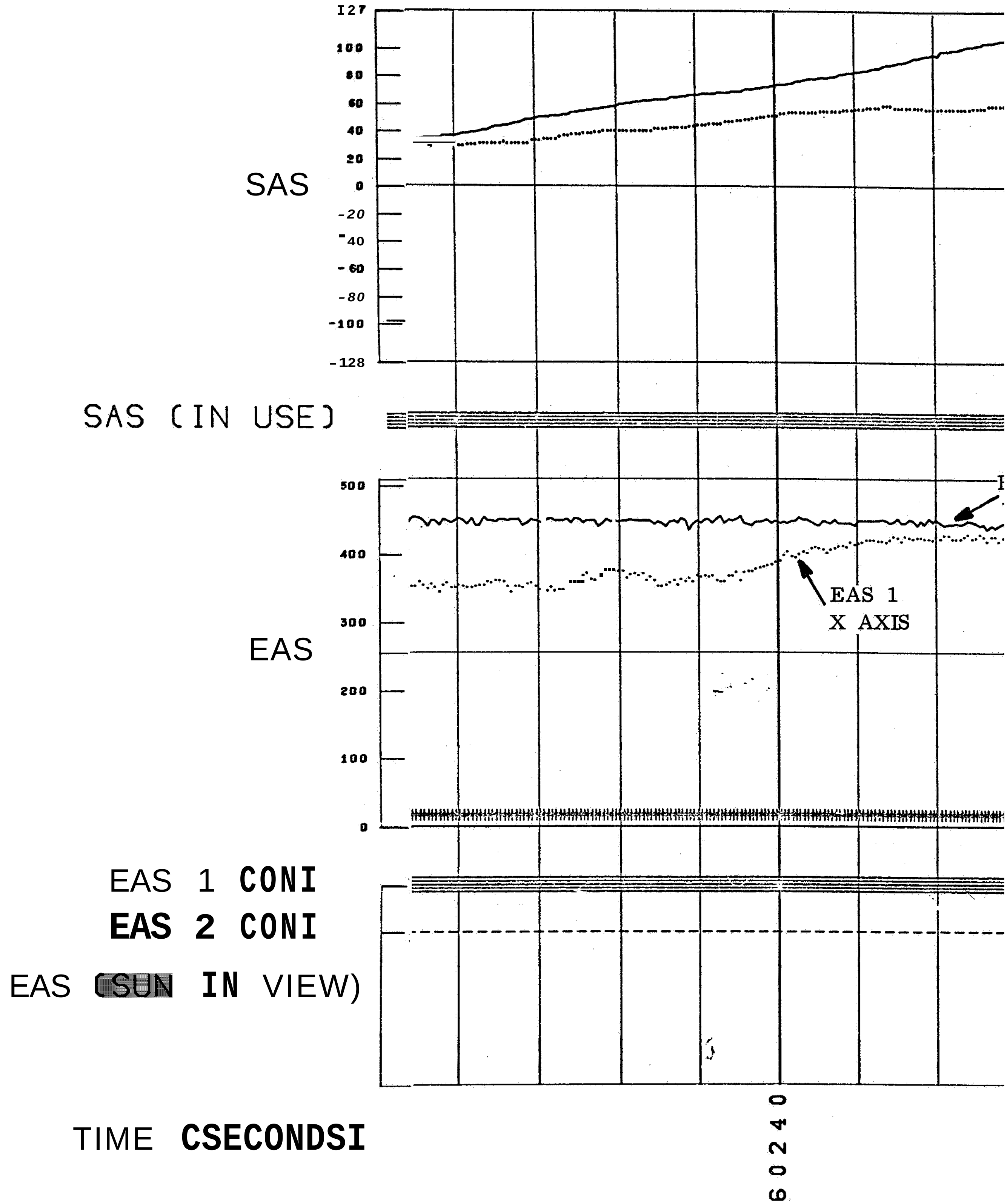
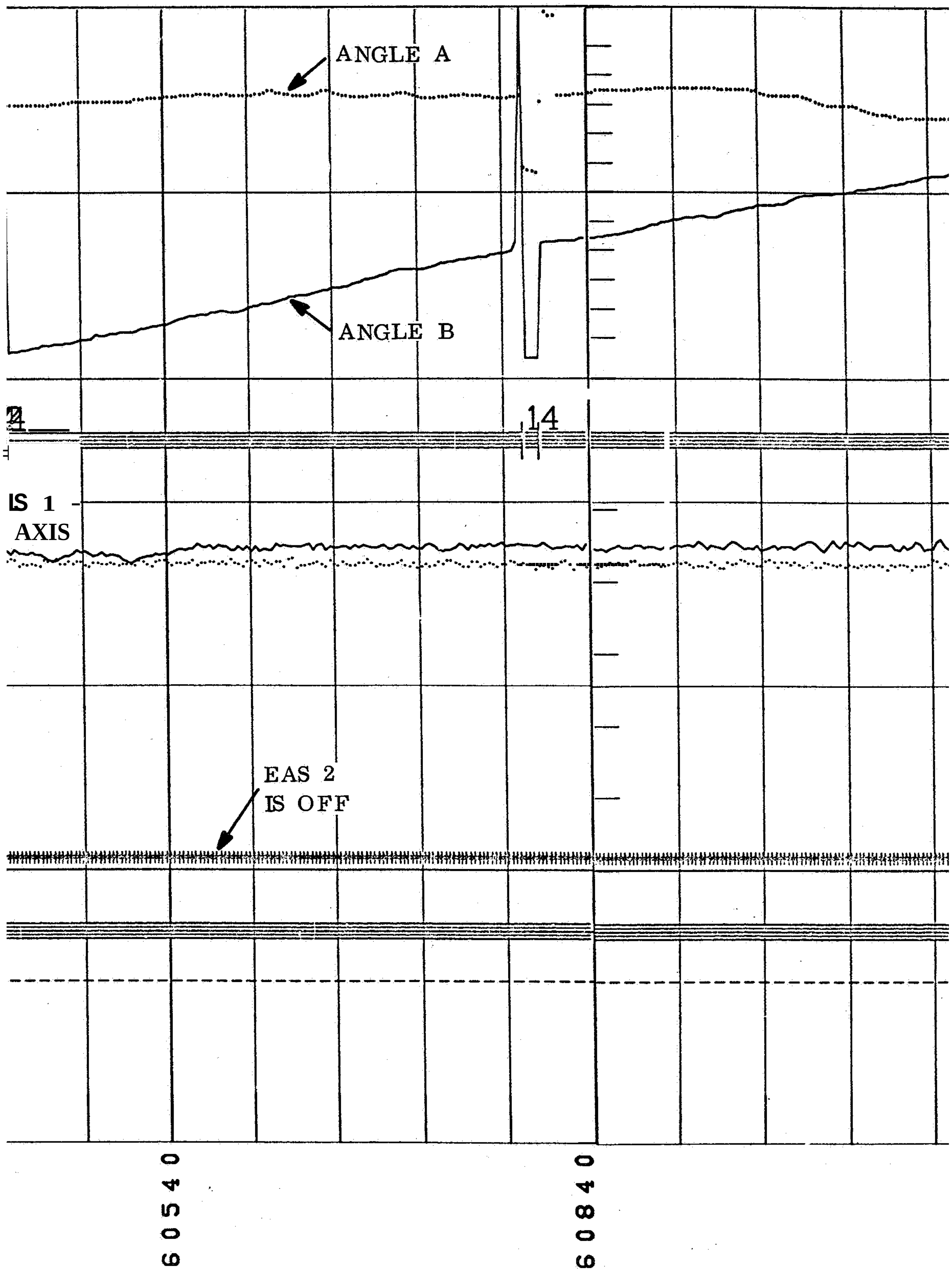


Figure 2-3. Spacecraft Pointing Attitude - Day 96

PAGES 2-19, 2-20, MISSING FROM ORIGINAL MANUSCRIPT.



SAS
SAS (IN USE)
EAS
EAS 1 X AXIS
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
TIME (SECONDS)
60240


ANGLE A
ANGLE B
14
IS 1
AXIS
EAS 2
IS OFF
60540
60840

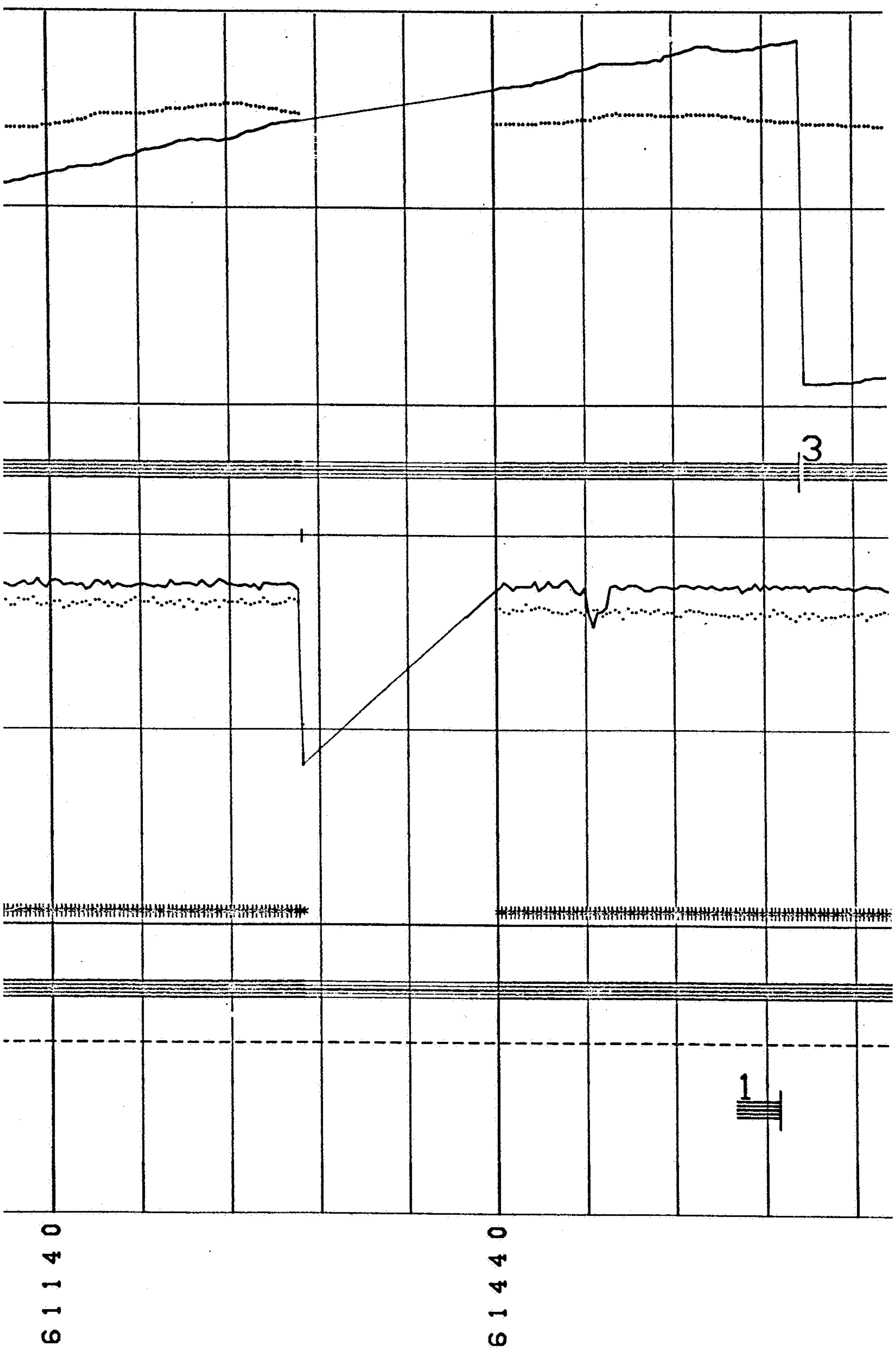
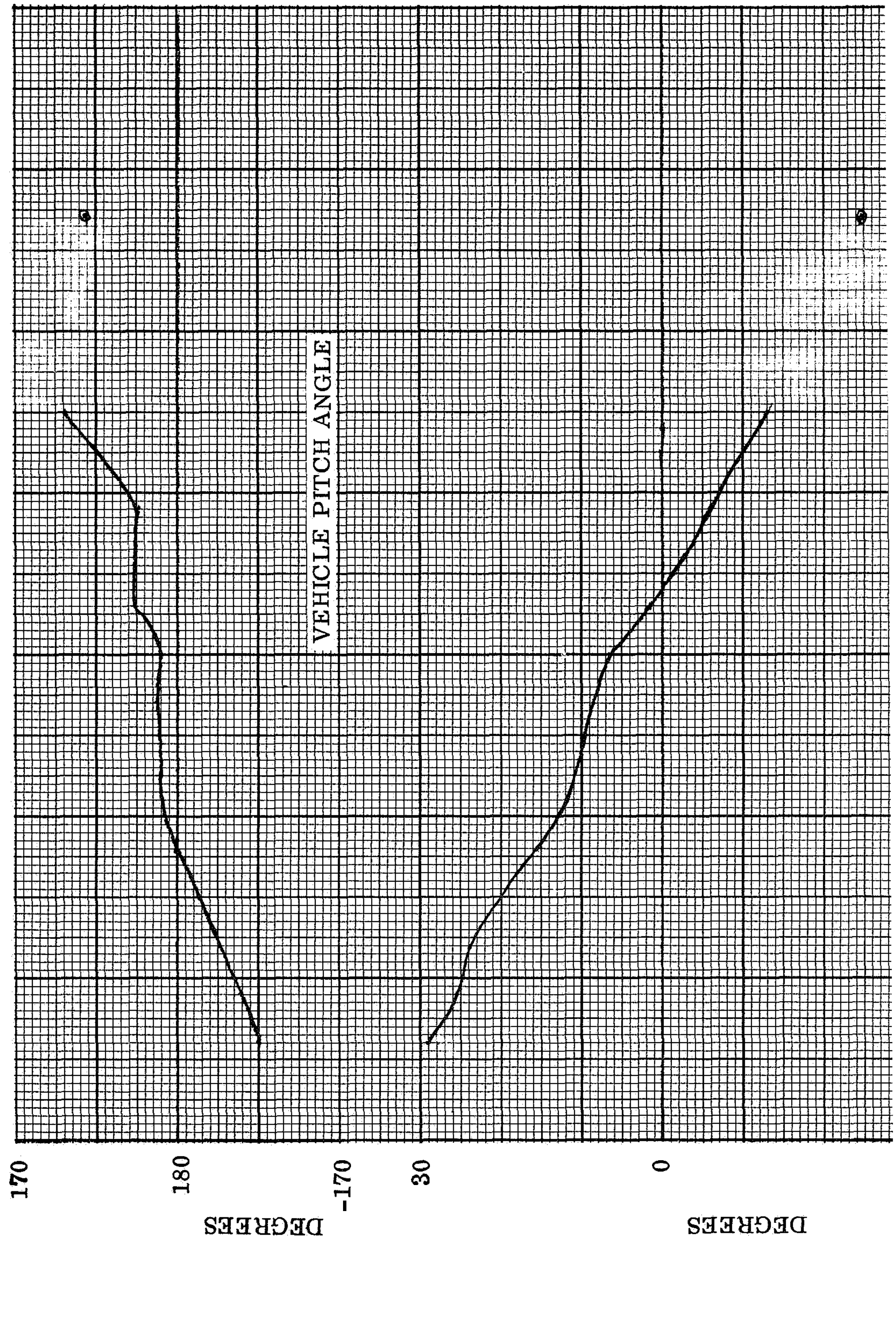


Figure 2-4. Attitude Sensor Data (2) -
Day 96: Part 2


VEHICLE PITCH ANGLE
DEGREES
170
180
-170
30
0
DEGREES

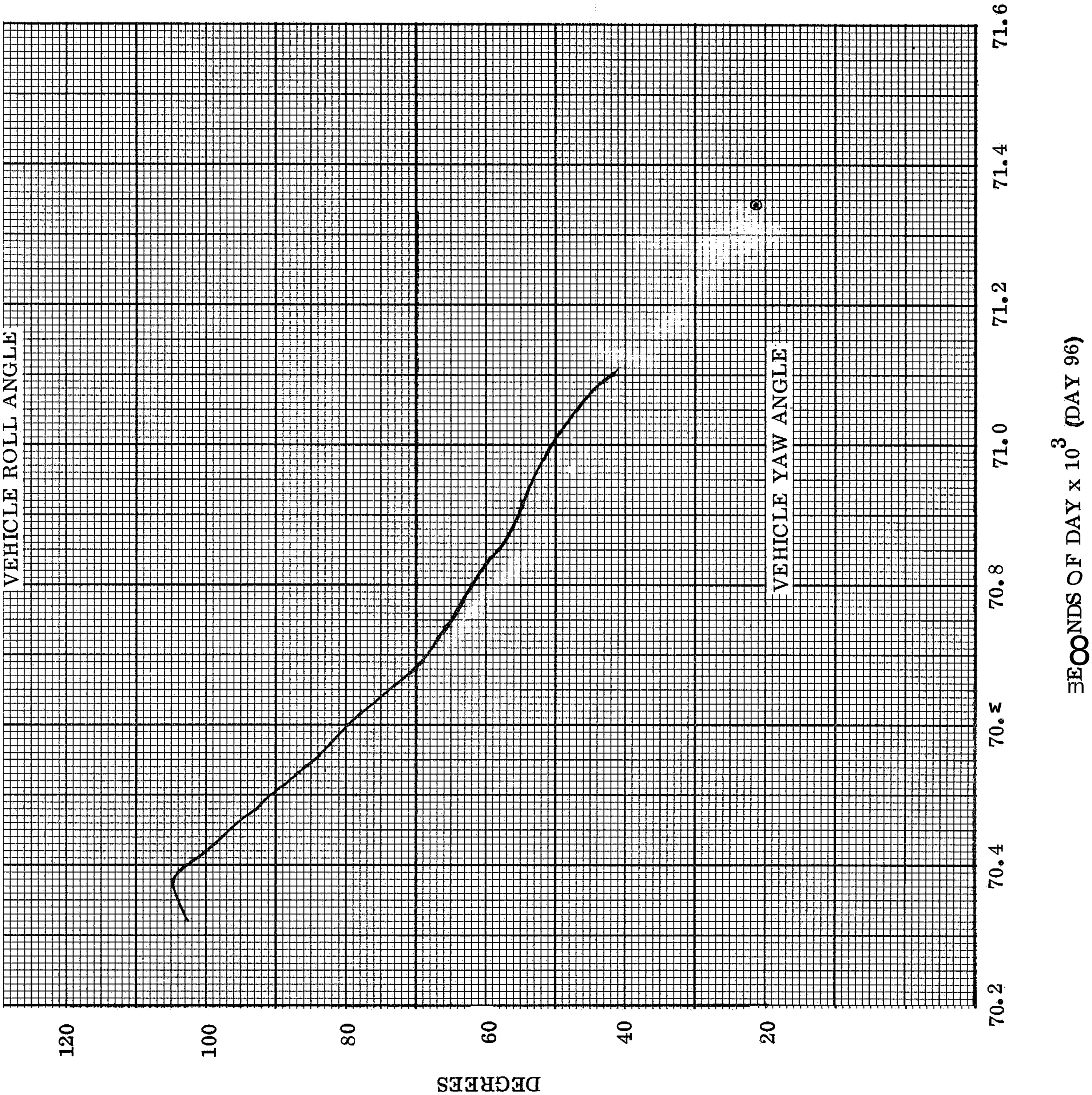


Figure **2-5. Computed Attitude (2) - Day 96**

Based on attitude sensor data obtained from the first **14** days of flight, the spacecraft appears to be continually tumbling. The observed tumble rate during Days **98** through **109** is comparable to tumbling rates observed during Days **96** and **97.** The highest tumble rate (26.5 degrees per minute) was observed at 50,000 seconds of Day **99.** In several instances, the attitude sensor data indicates a yaw inversion.

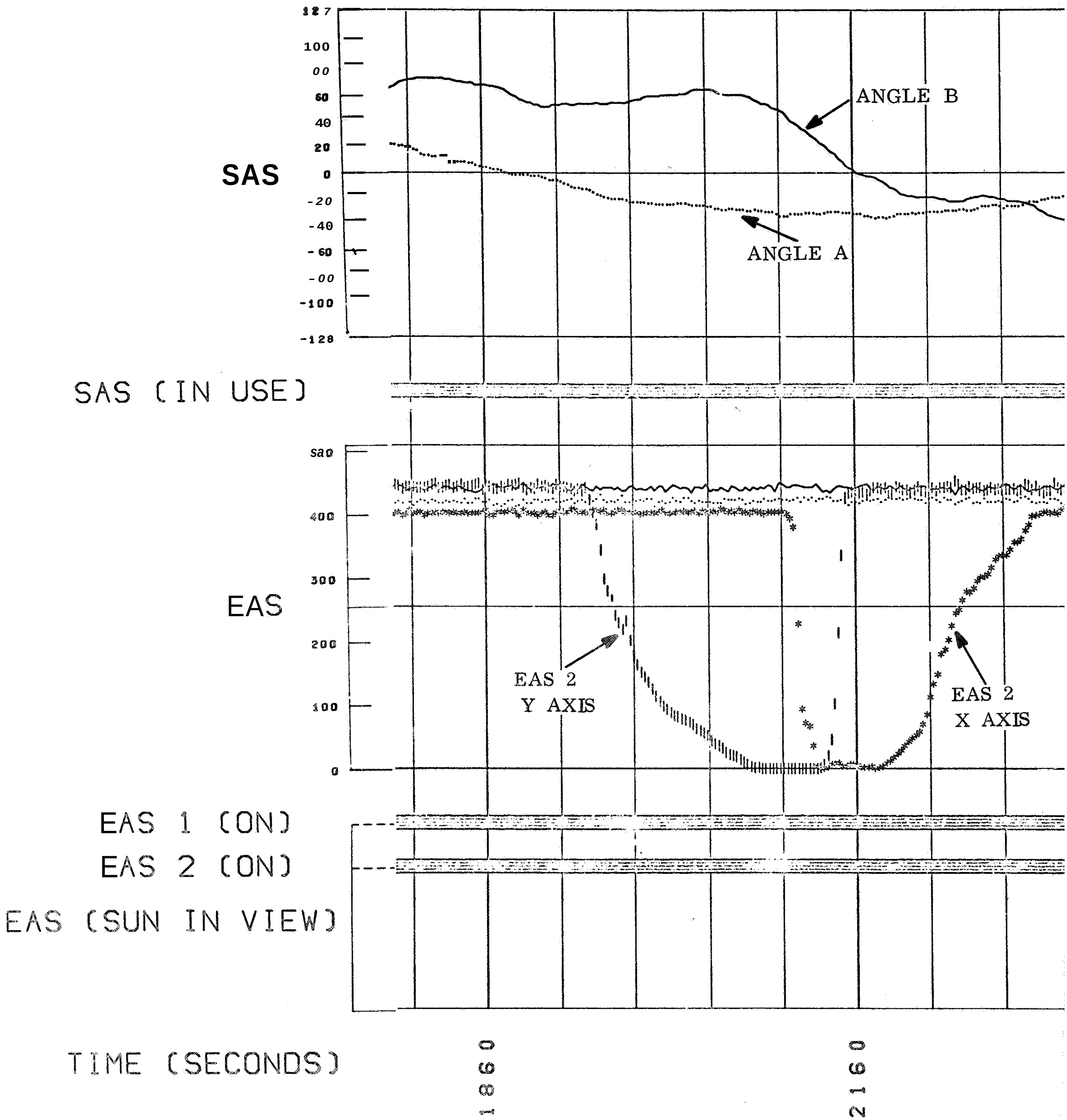
Figures **2-6** through **2-9** show spacecraft tumbling indicated by both IR Sensors and the Solar Aspect Sensor. The indicated spacecraft attitude is summarized in Figure 2-10.

Although the spacecraft tumble rate has not increased significantly since the first day of flight, attitude sensor data indicates the spacecraft central body to be perturbed by the motion of the boom system. This effect is discussed in Section 2.4.

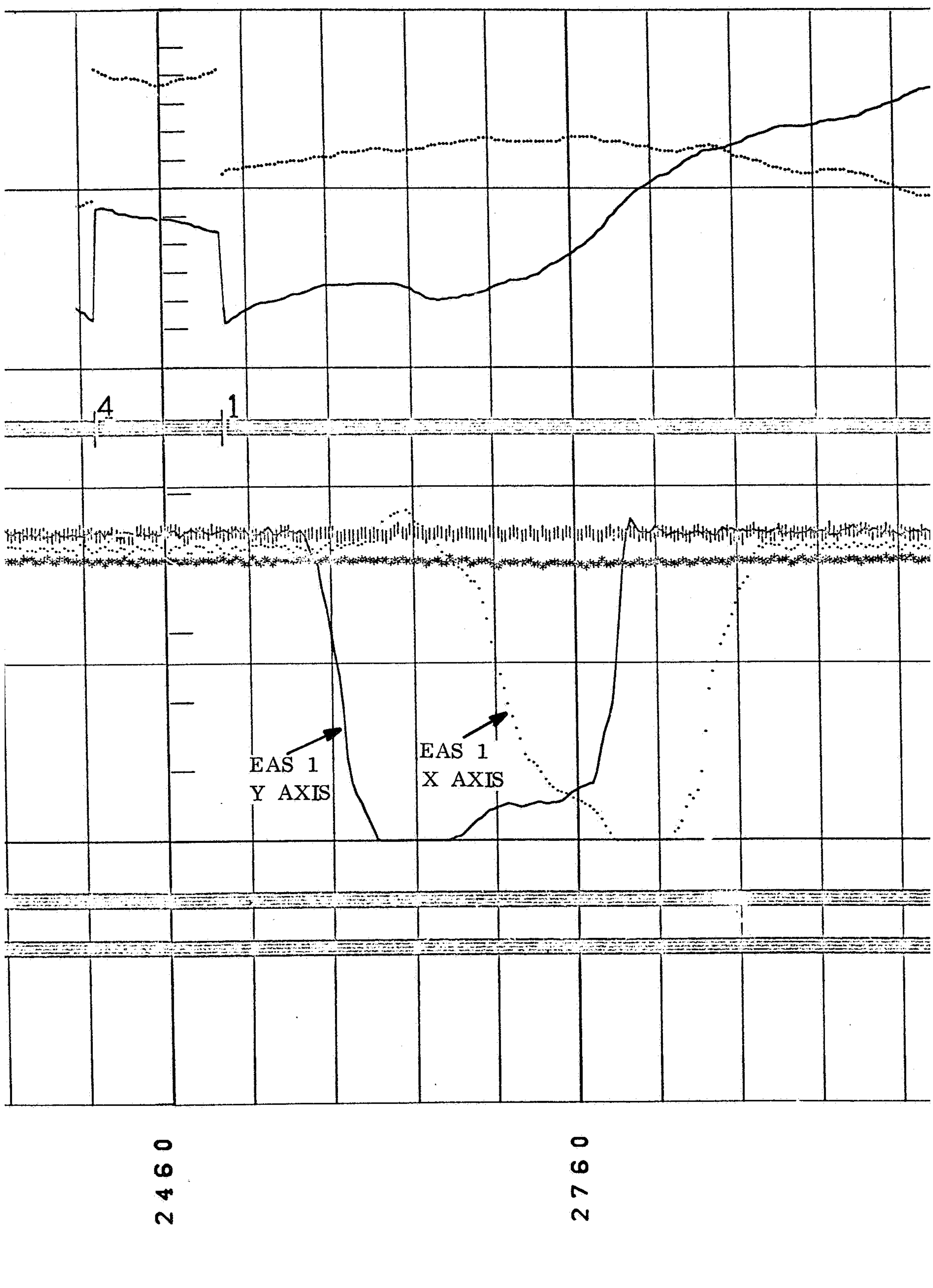
2.2.3.2 Stabilization Performance Analysis

The high value of the orbit eccentricity (0.455) precludes stabilization of the spacecraft in the gravity gradient mode. The large variation of the angular rate of the radius vector makes it impossible for the spacecraft to establish a meaningful average angular rate, which is required for gravity gradient control. As a result, large angular deviations from the local vertical will constantly cause large gravity gradient torques to act on the spacecraft. These will appear as disturbance torques, rather than control torques. The magnitude of the torques vary by a factor of 20 between apogee and perigee because of the altitude change. A large angle digital computer run was made using the ATS Mathematical Model to investigate possible spacecraft motion. At the time of the run, the model was limited in two areas as applied to the anomalous orbit. The approximation for eccentricity beyond $E = 0.1$ has error associated with it and aerodynamic torques are not simulated in the mathematical model. At a perigee of **100** nm, the aerodynamics causes a large disturbance since the dynamic pressure is four orders of magnitude greater than solar pressure. This is probably the most significant simulation deviation from actual conditions.

Figure 2-11 is the result of the computer run. The initial phases of the run depict the rod extension and capture phase. The initial conditions were estimated from early data.



SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
ANGLE B
ANGLE A
SAS (IN USE)
EAS
500
400
300
200
100
0
EAS 2
Y AXIS
EAS 2
X AXIS
EAS 1 (ON)
EAS 2 (ON)
EAS (SUN IN VIEW)
TIME (SECONDS)
1860
2160



2-28-1

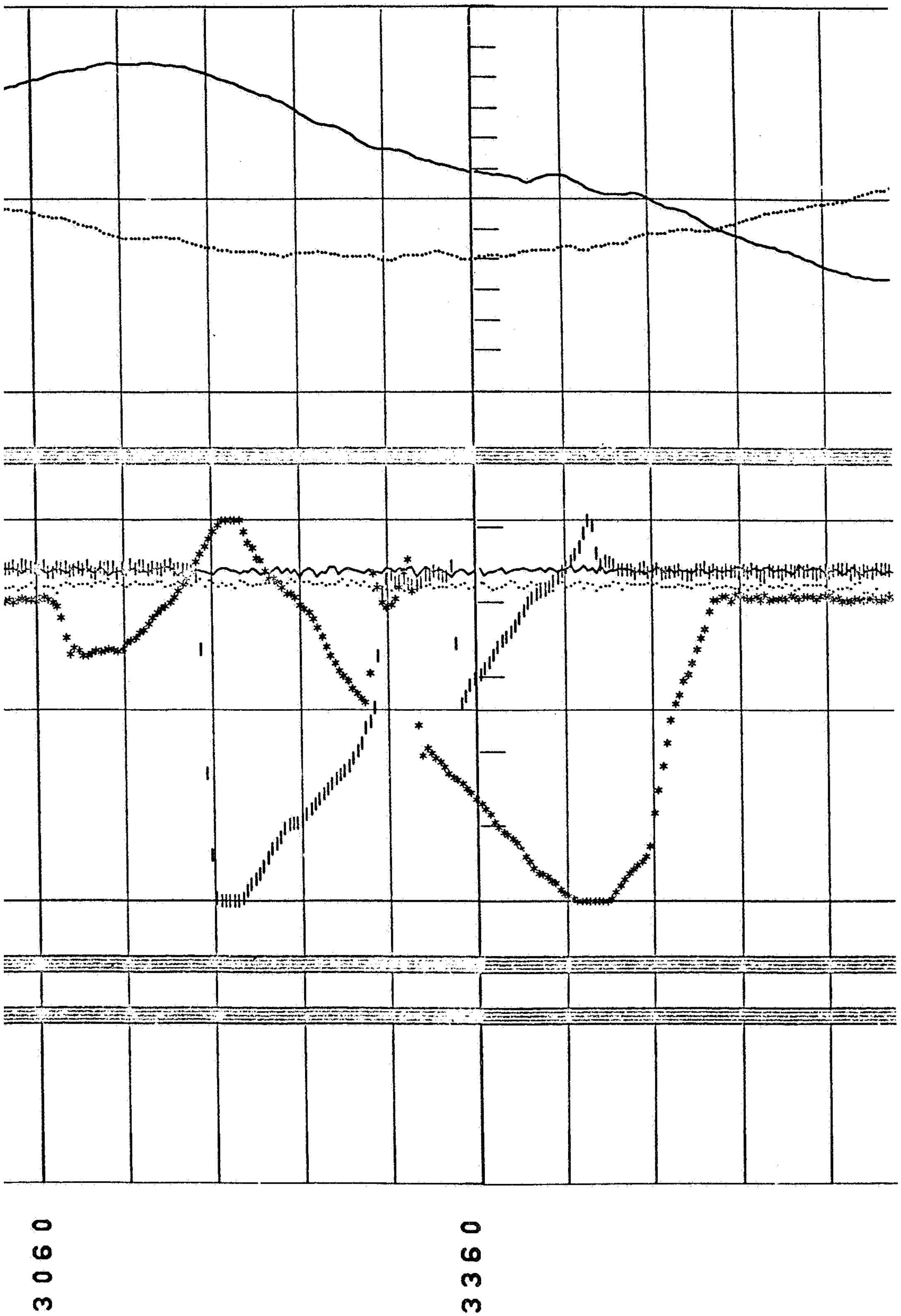
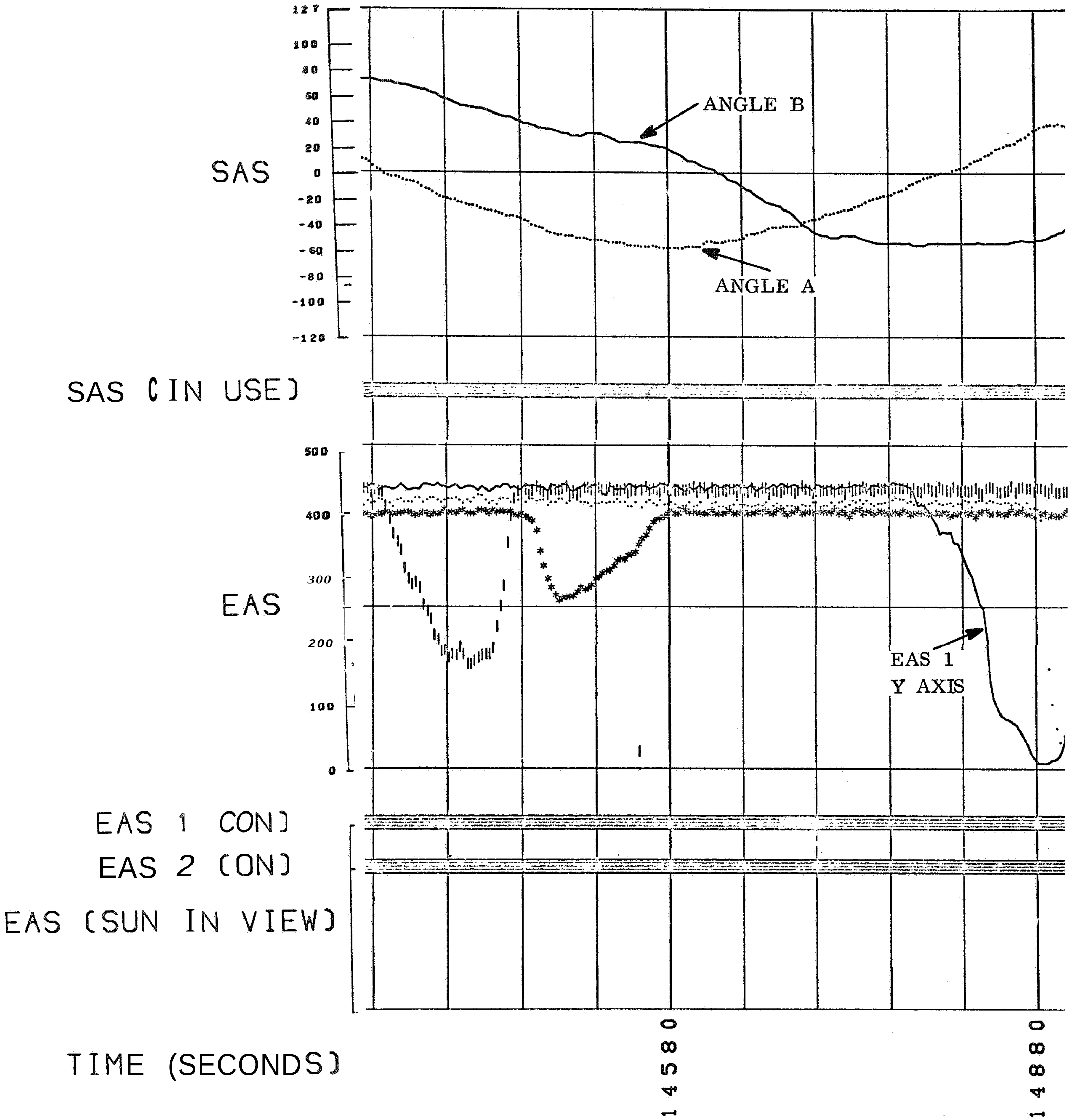
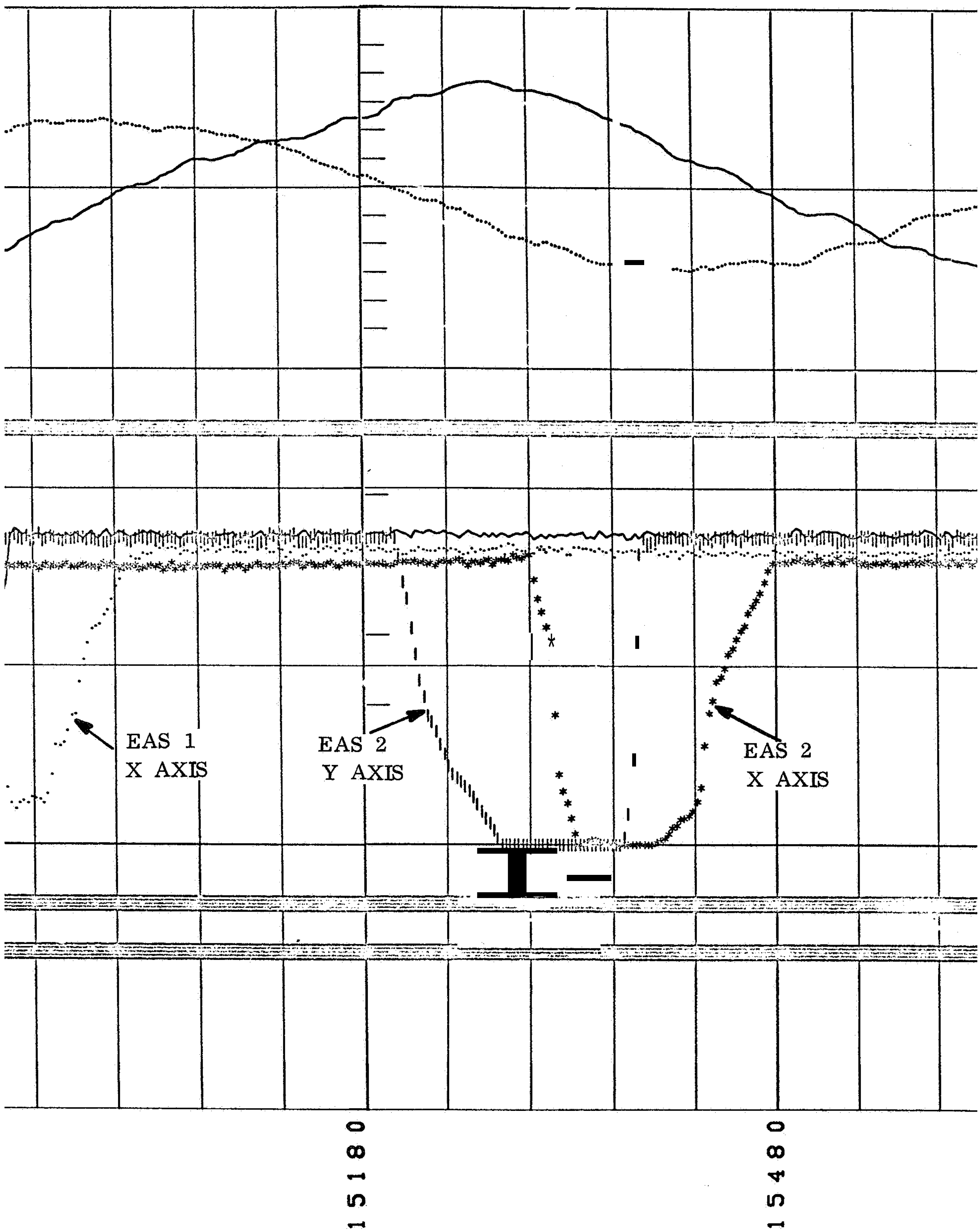


Figure 2-6. Attitude Sensor Data (1)- Day 97

2-28-2
[redacted]



SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
ANGLE B
ANGLE A
SAS (IN USE)
EAS
500
400
300
200
100
0
EAS 1
Y AXIS
EAS 1 (ON)
EAS 2 (ON)
EAS (SUN IN VIEW)
TIME (SECONDS)
14580
14880


EAS 1
X AXIS
EAS 2
Y AXIS
EAS 2
X AXIS
15180
15480

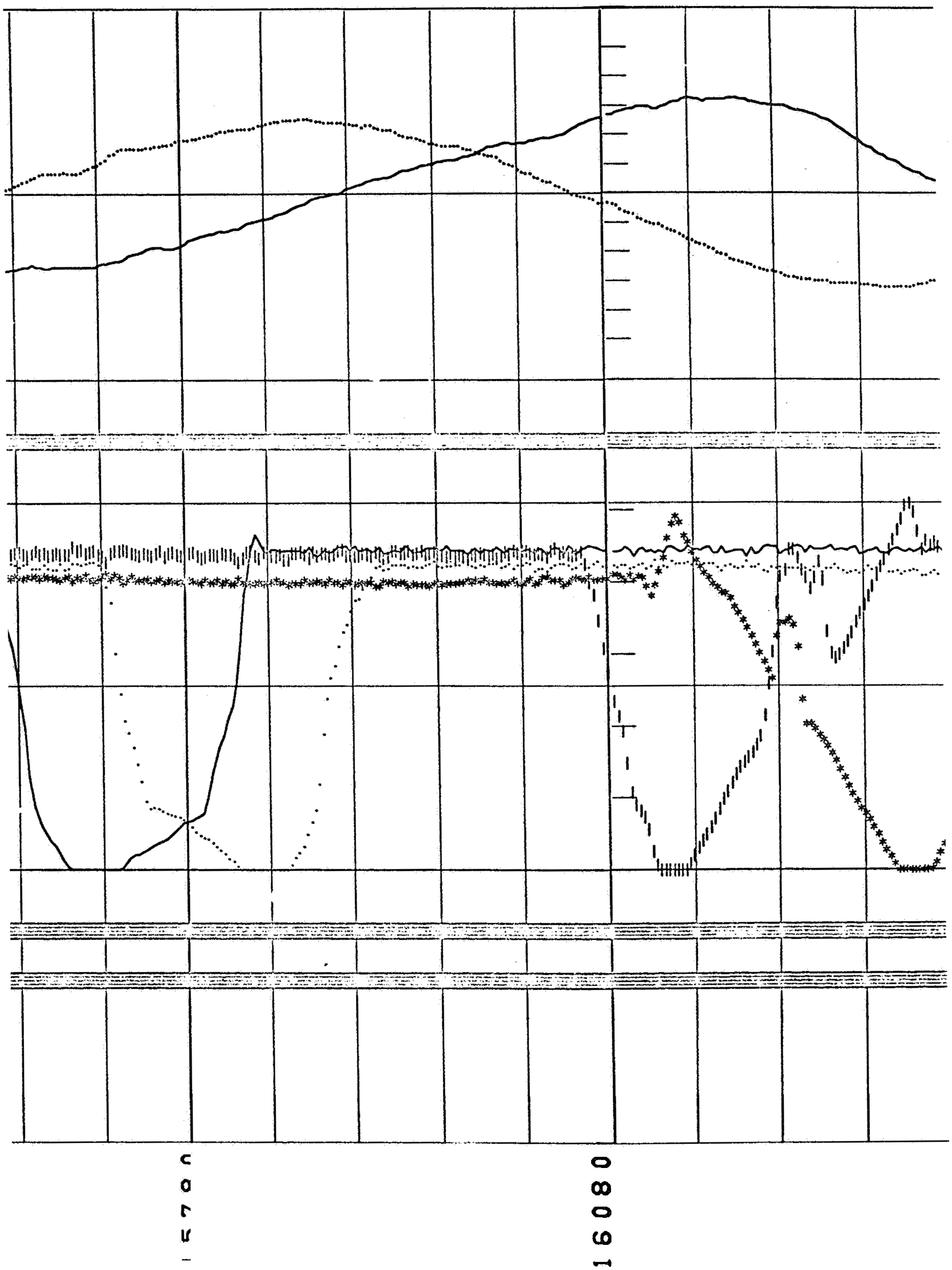
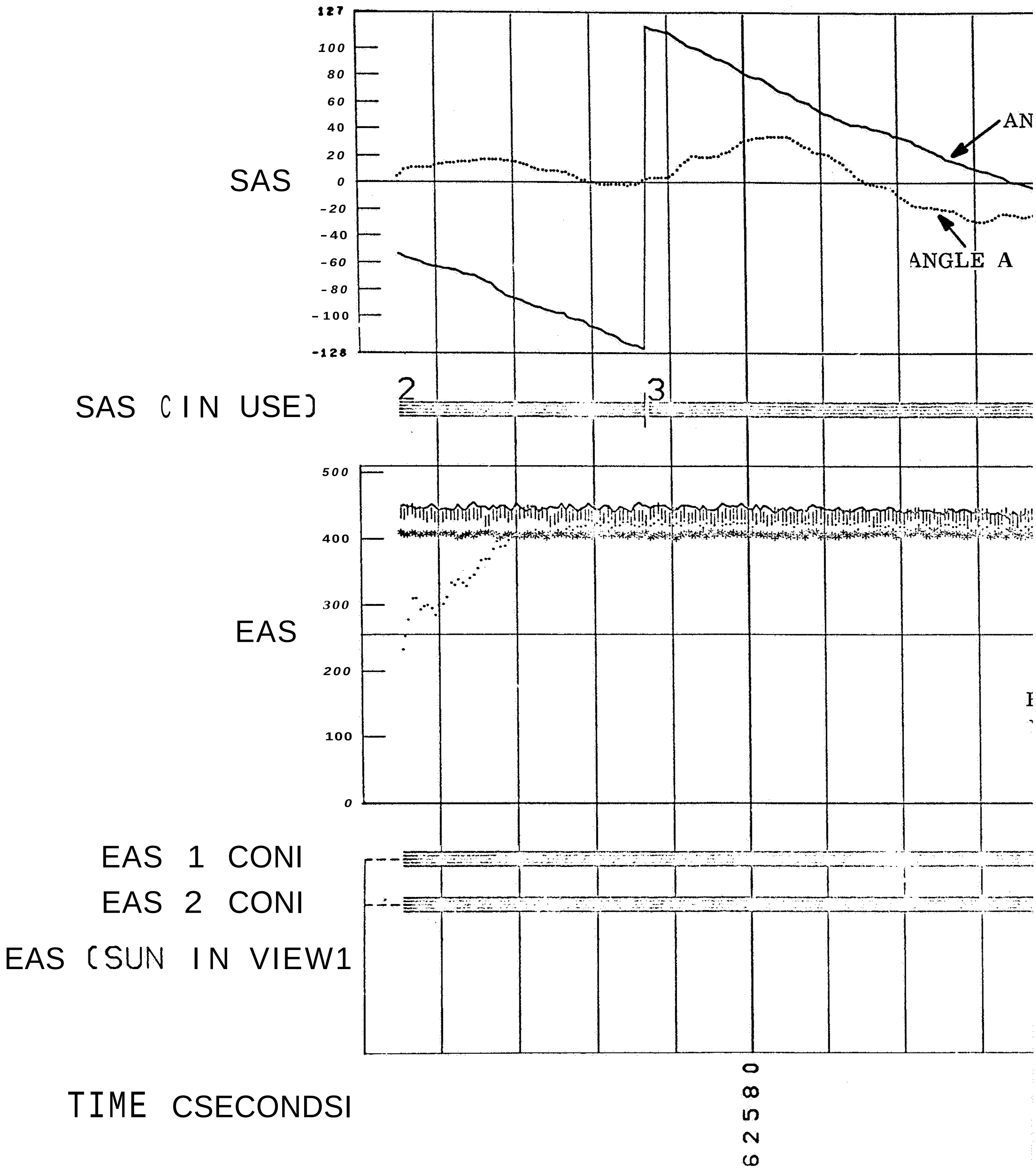
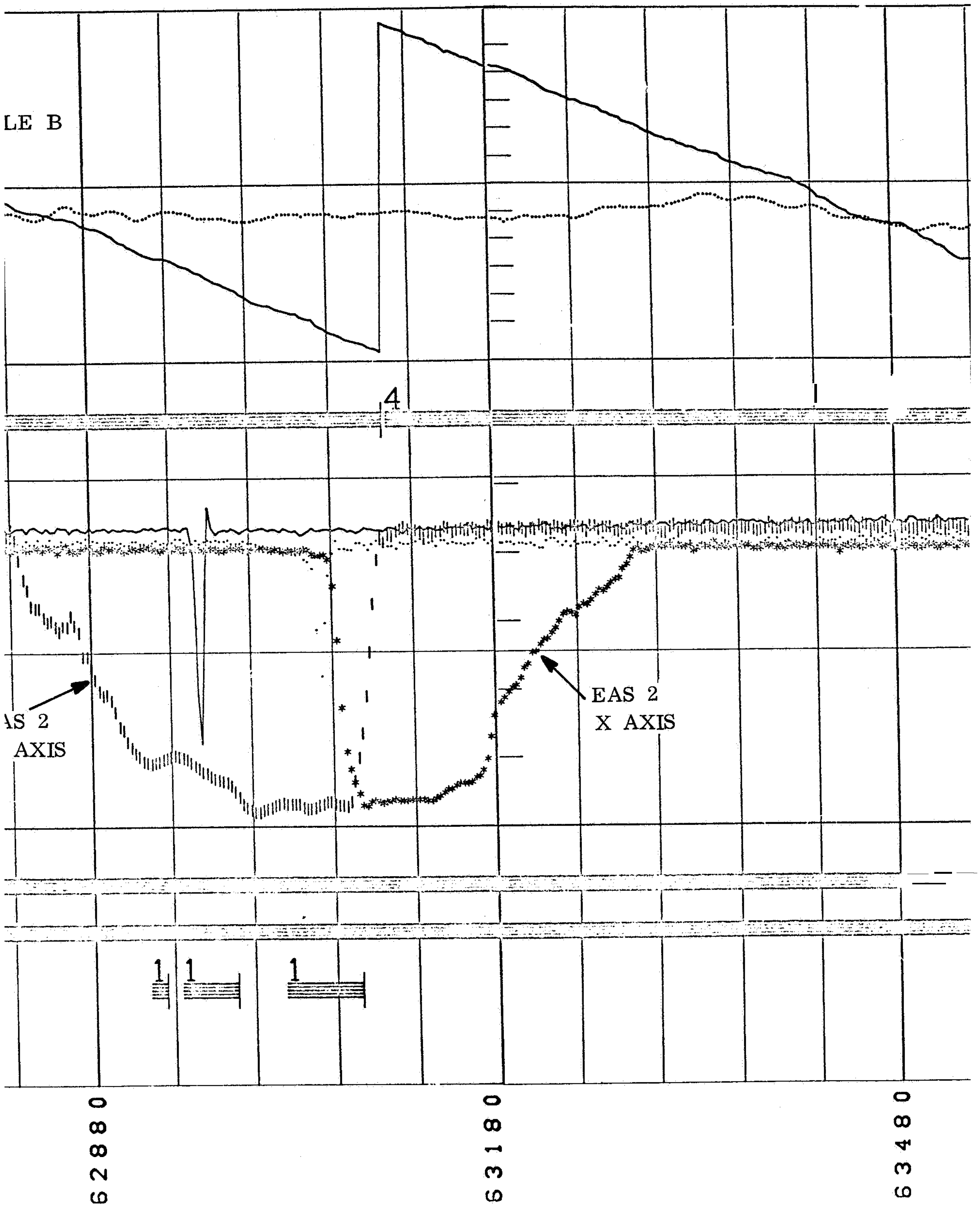


Figure 2-7. Attitude Sensor Data (2) - Day 97

[redacted]



127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS
AN
ANGLE A
2
3
SAS (IN USE)
500
400
300
200
100
0
EAS
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW1
TIME CSECONDSI
62580


LE B
4
EAS 2
X AXIS
AS 2
AXIS
1
1
1
62880
63180
63480

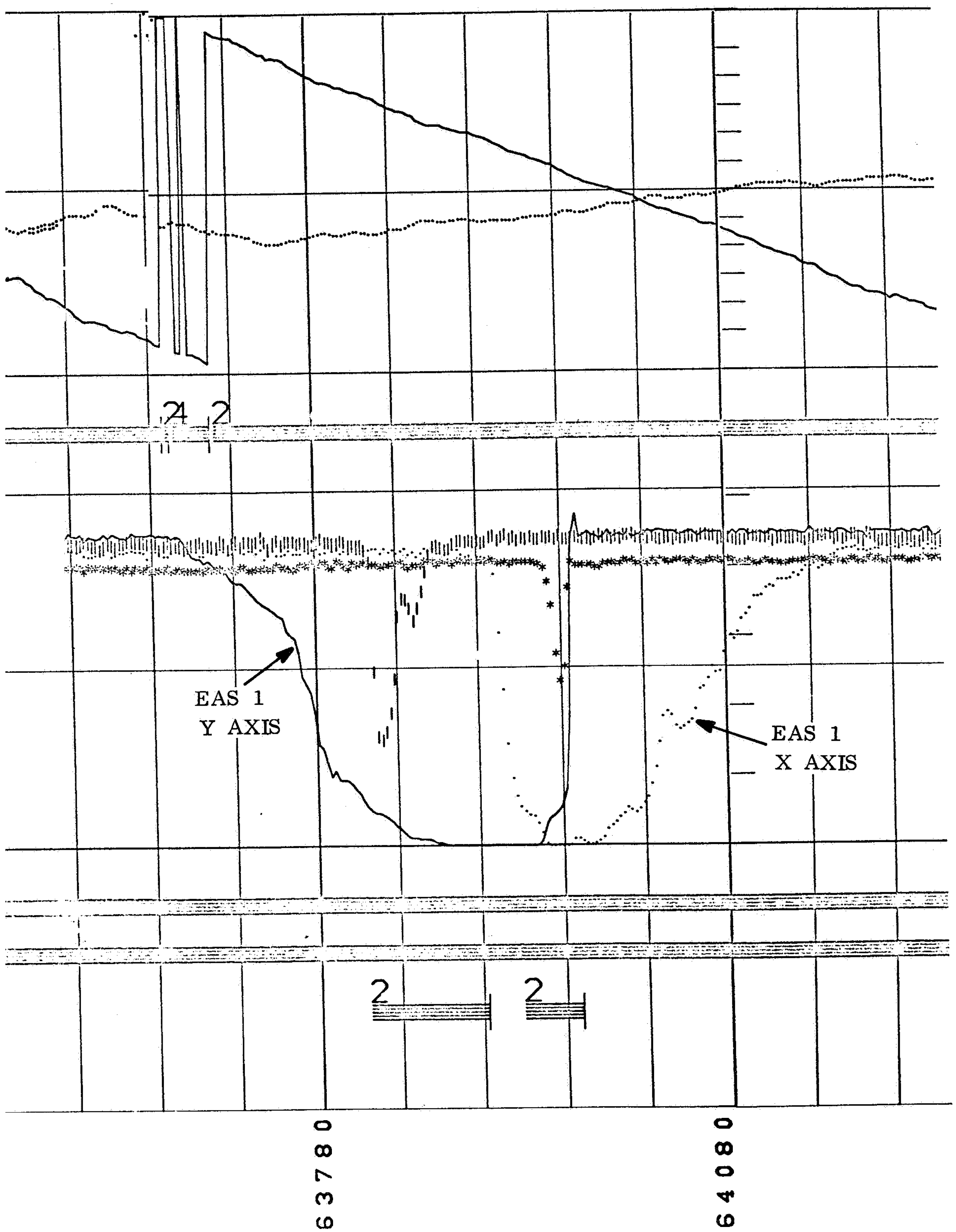
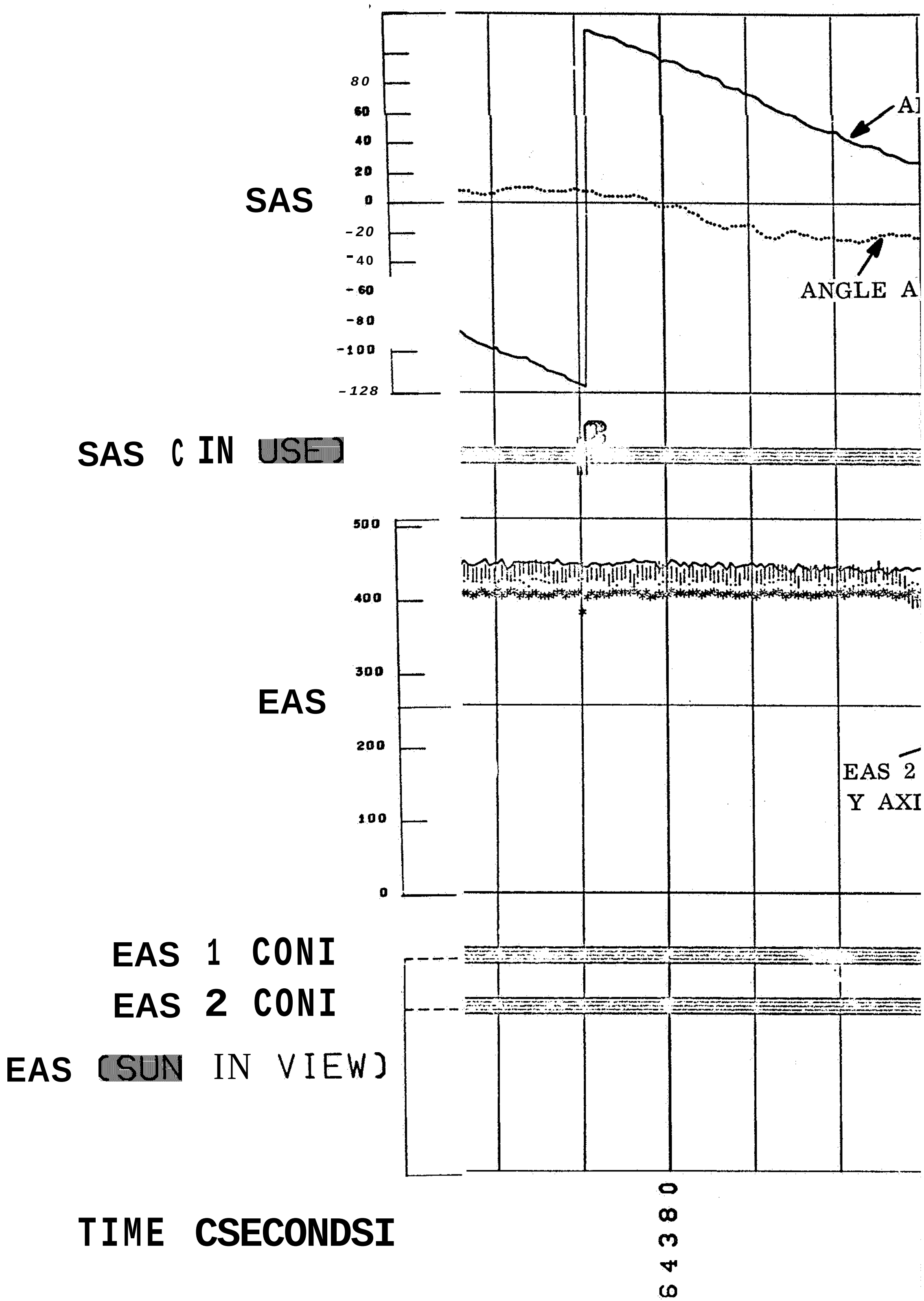
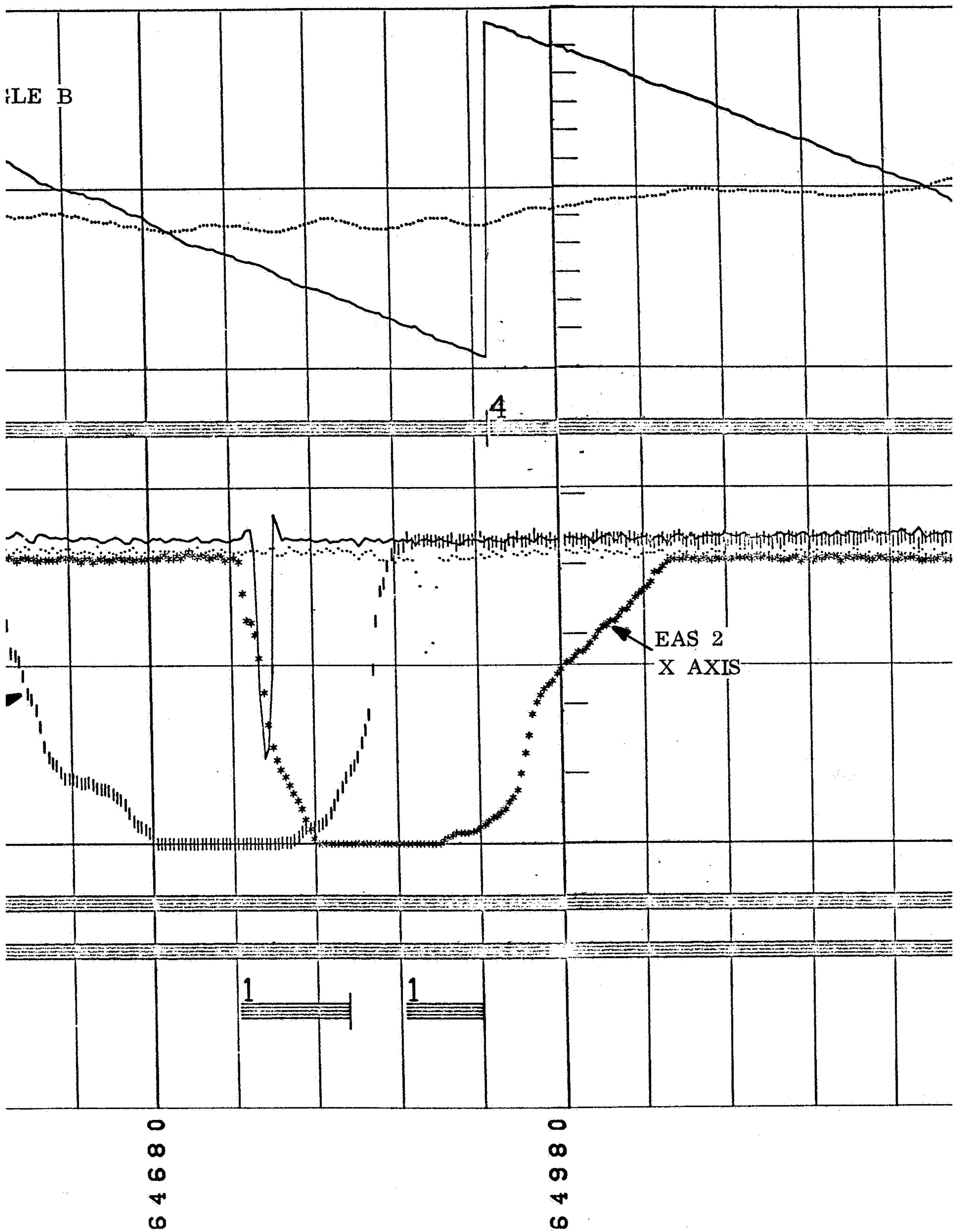


Figure 2-8. Attitude Sensor Data (3) - Day 97:
Part 1


SAS
80
60
40
20
0
-20
-40
-60
-80
-100
-128
ANGLE A
SAS (IN USE)
500
400
300
EAS
200
100
0
EAS 2
Y AXI
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
TIME (SECONDS)
64380



LE B
4
EAS 2
X AXIS
1
1
64680
64980

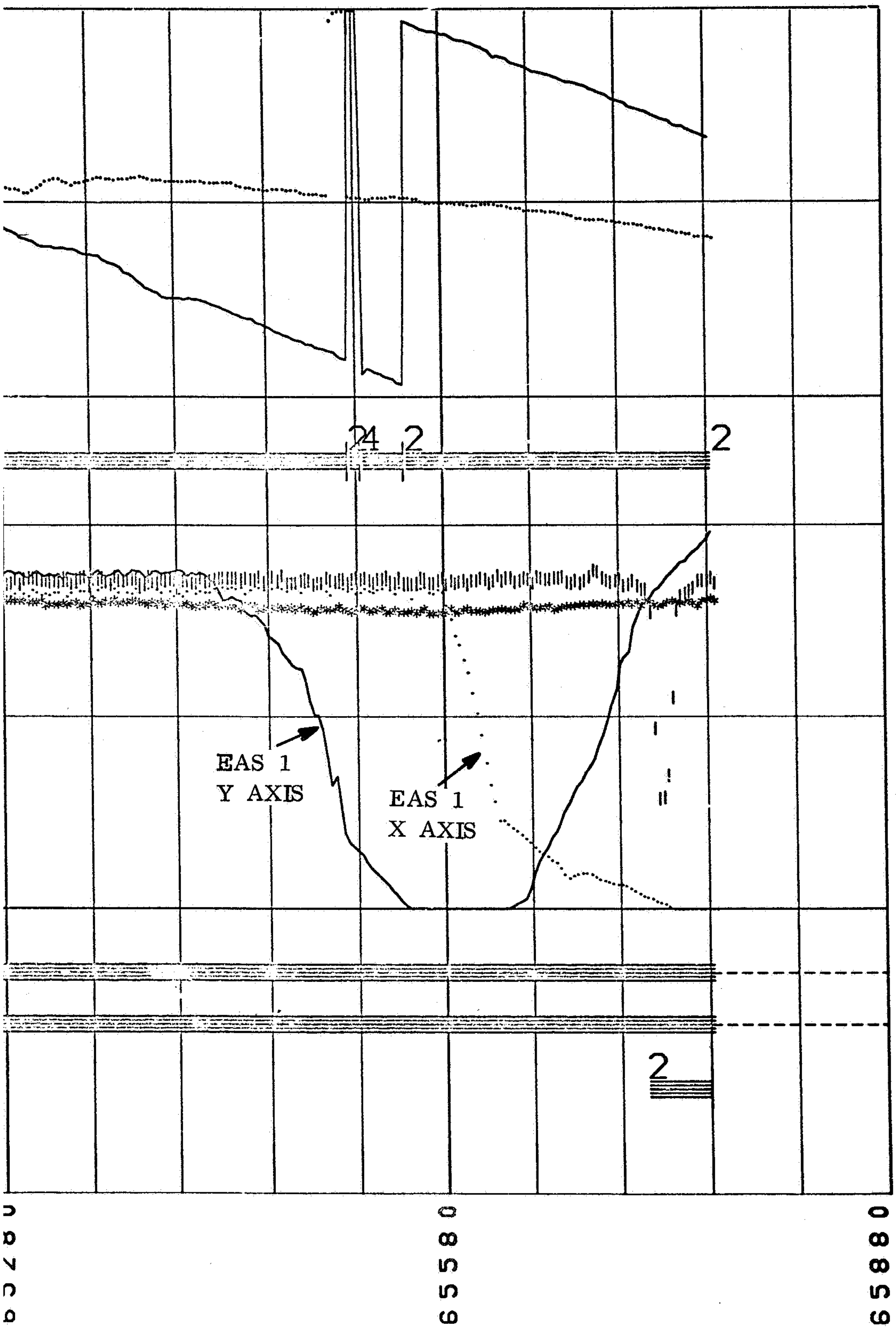
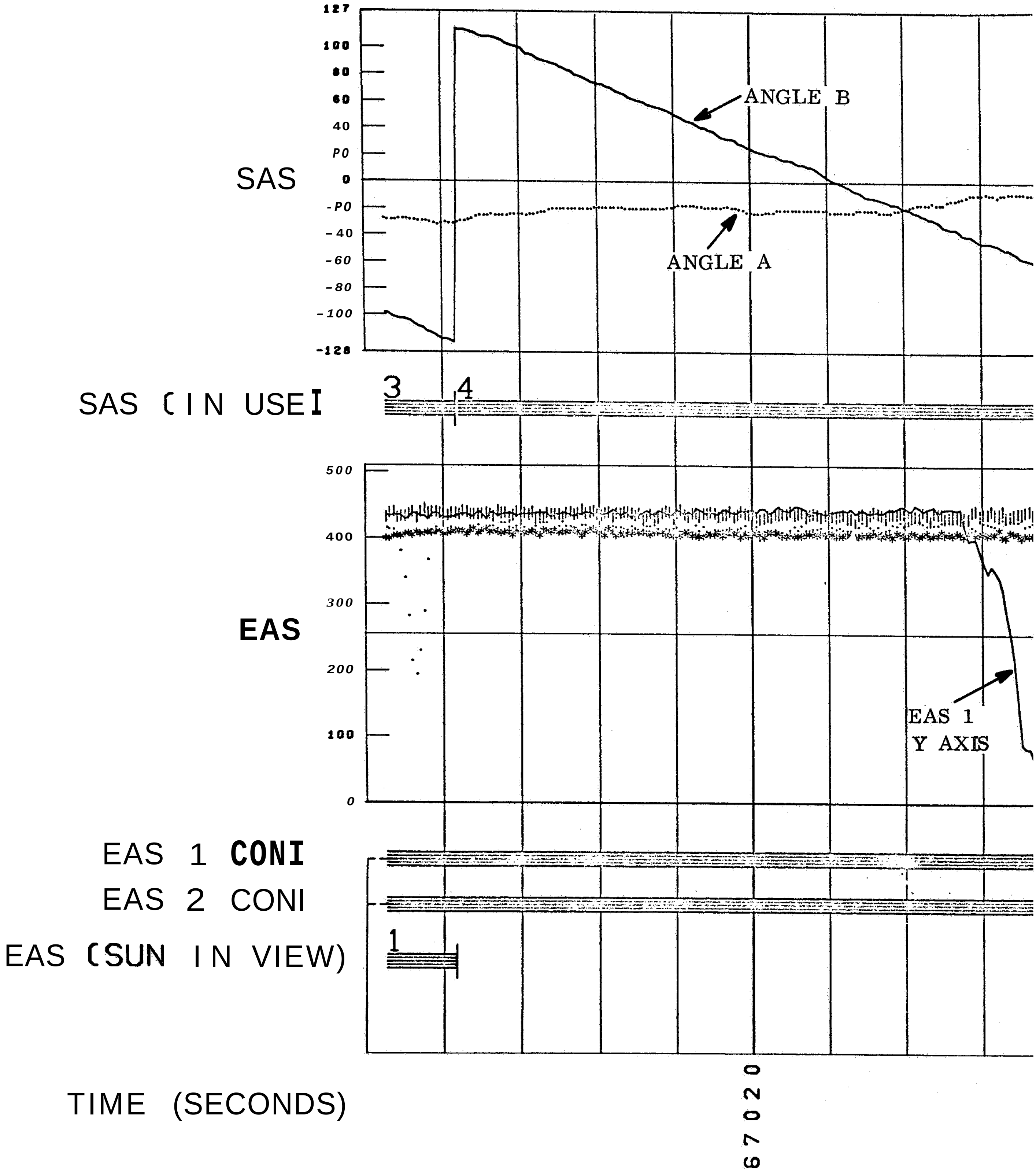
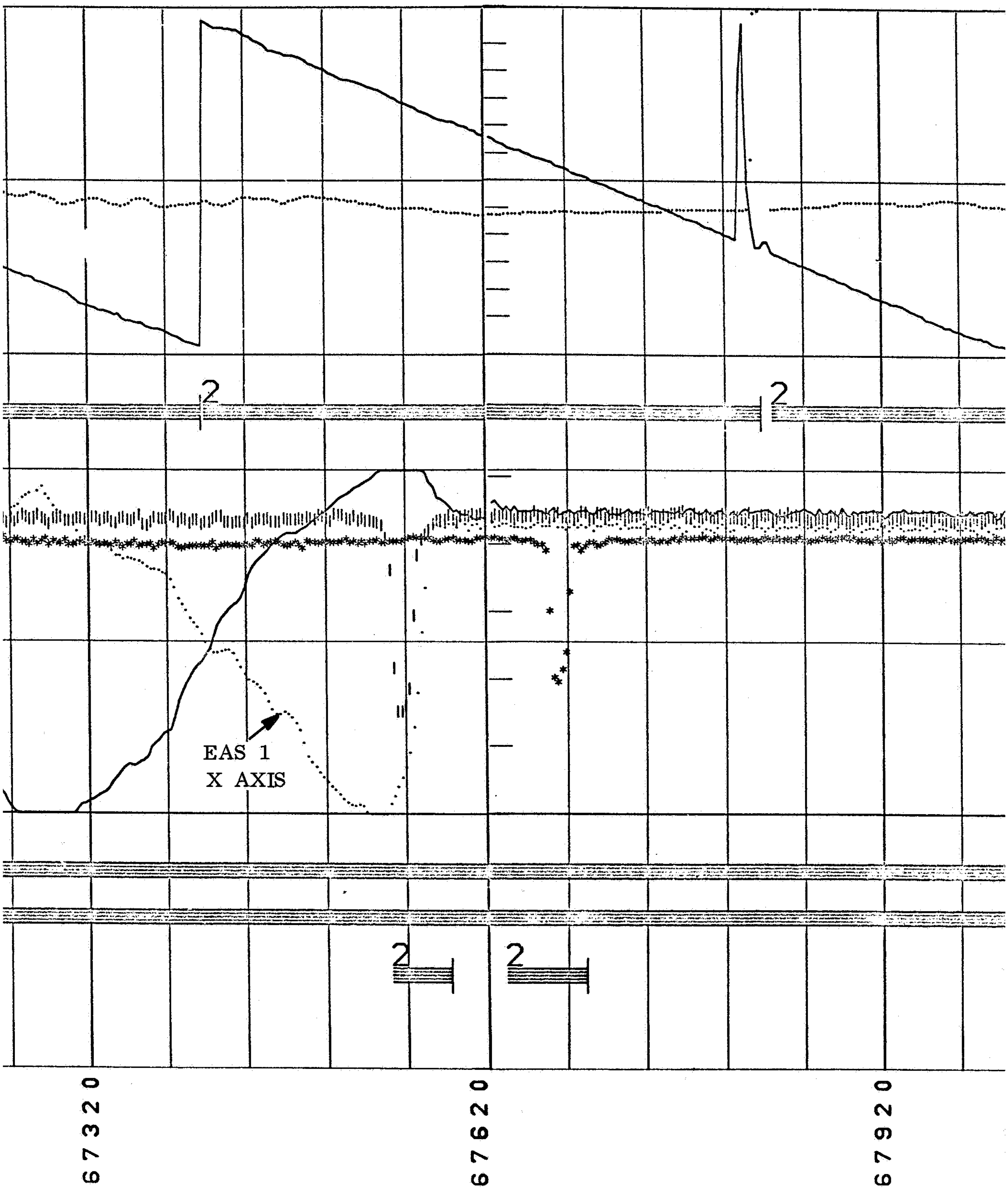


Figure 2-8. Attitude Sensor Data (3) -
Day 97: Part 2



SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
ANGLE B
ANGLE A
SAS (IN USE)
3
4
EAS
500
400
300
200
100
0
EAS 1
Y AXIS
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
1
TIME (SECONDS)
67020


EAS 1
X AXIS
67320
67620
67920

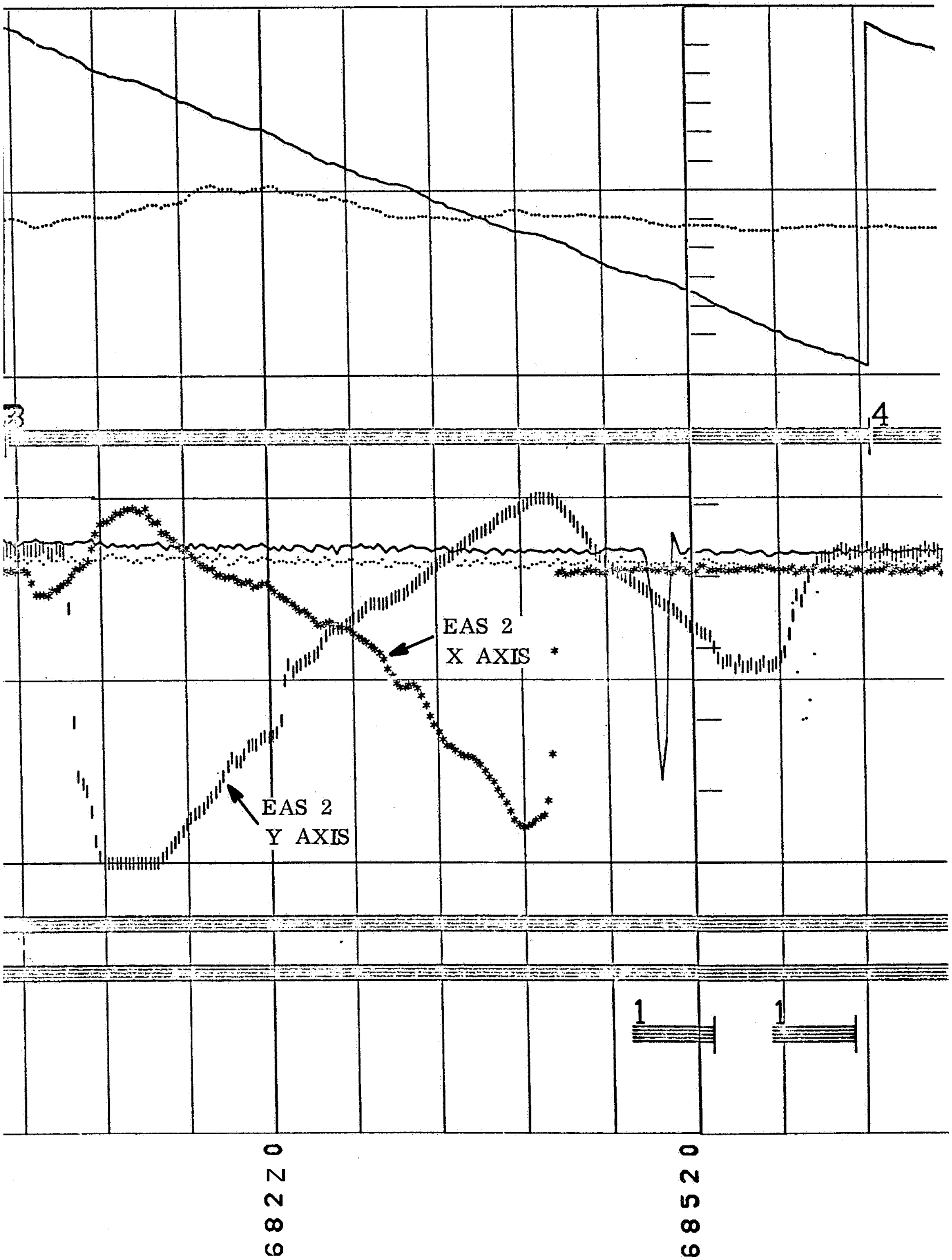


Figure 2-9. Attitude Sensor Data (4) - Day 97

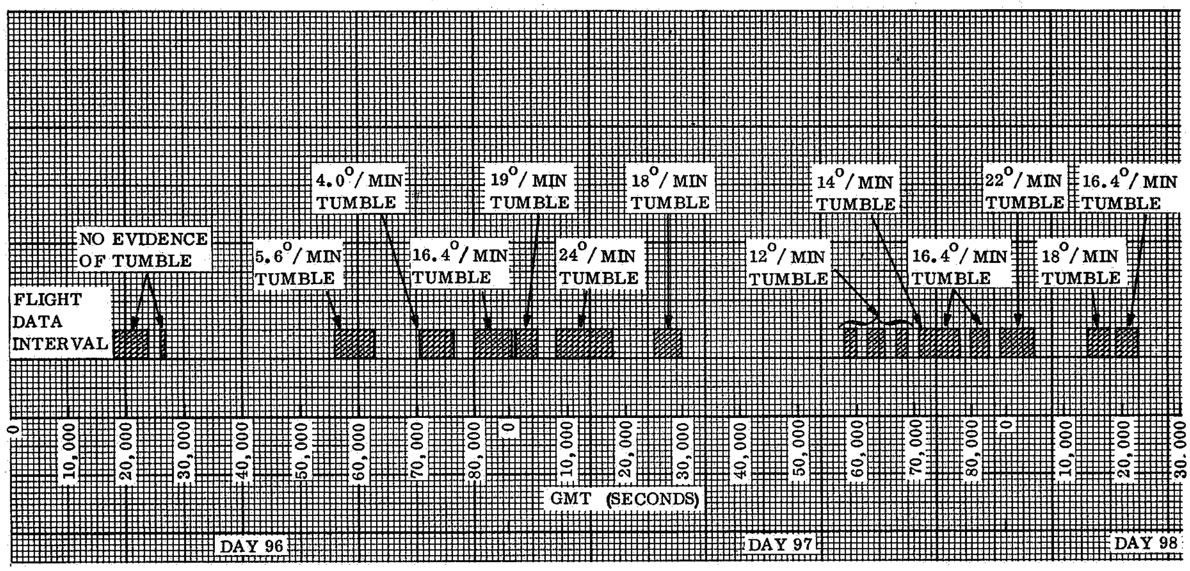


Figure 2-10. Indicated Attitude Performance Summary (Sheet **1)**

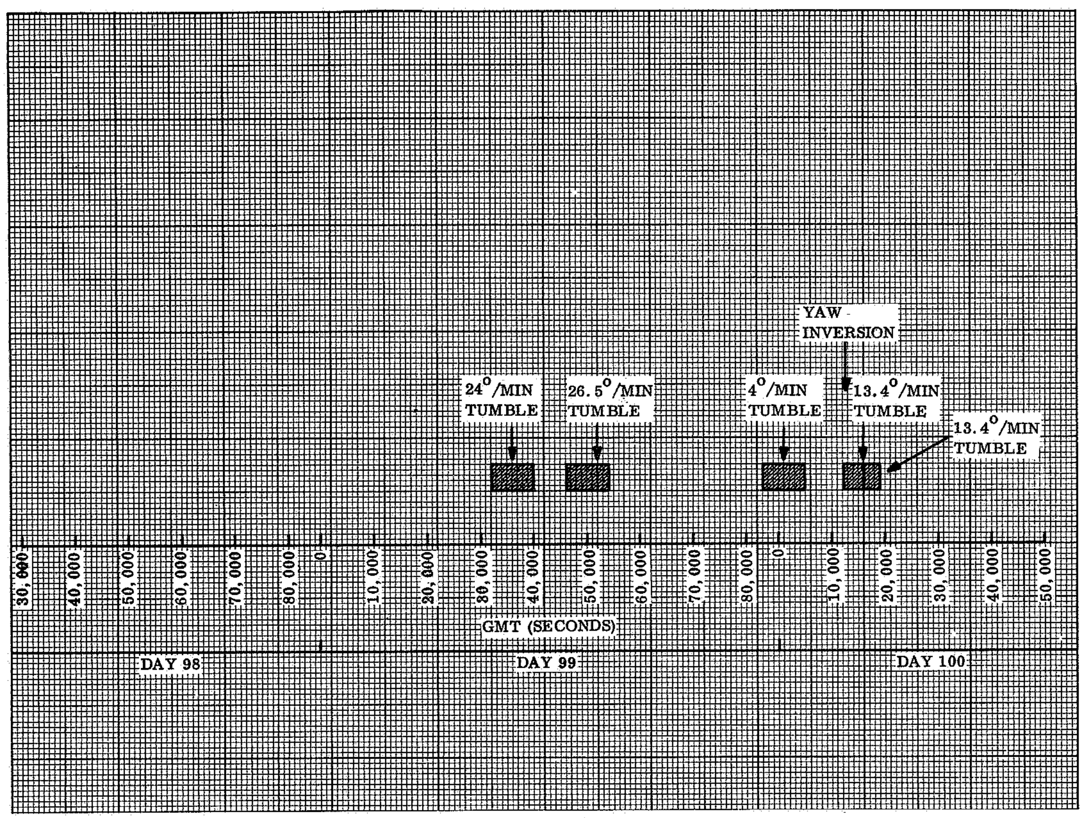


Figure **2-10.** Indicated Attitude Performance Summary (Sheet 2)

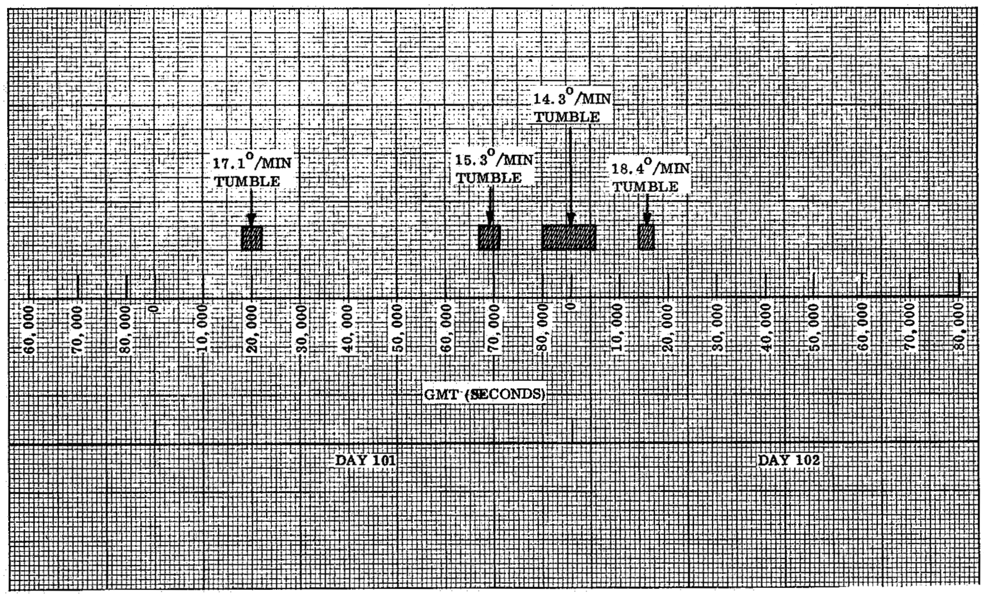


Figure 2–10. Indicated Attitude Performance Summary (Sheet 3)

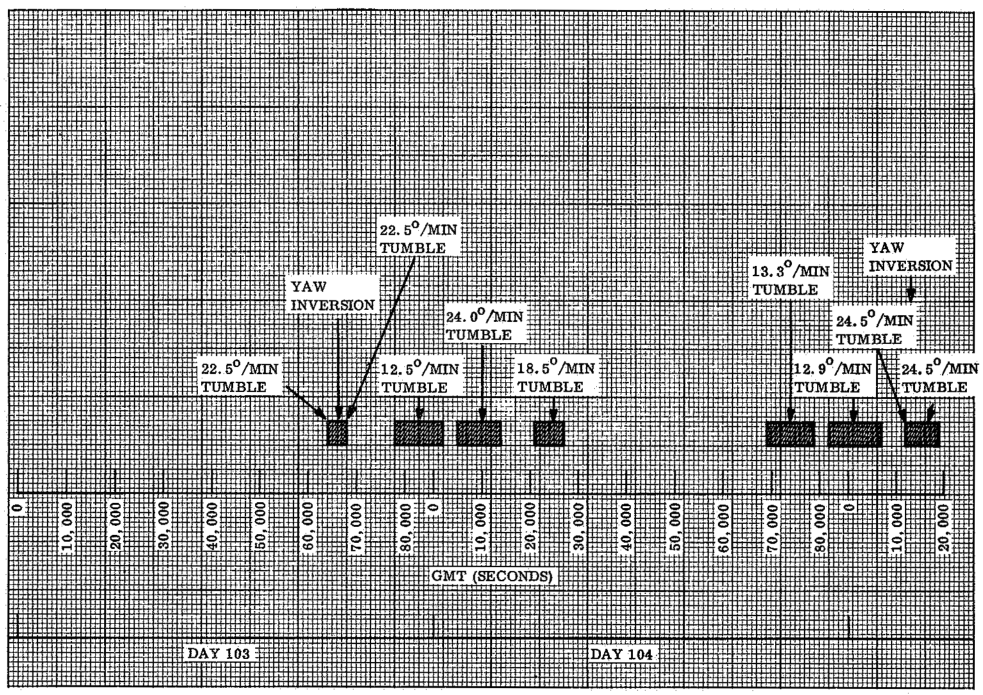


Figure 2–10. Indicated Attitude Performance Summary (Sheet 4)

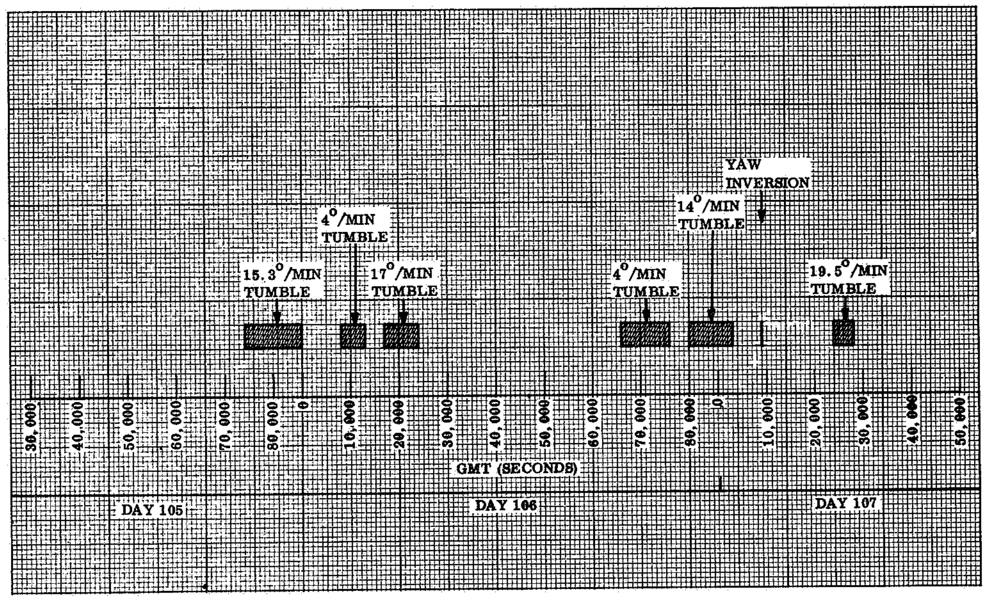


Figure 2–10. Indicated Attitude Performance Summary (Sheet 5)

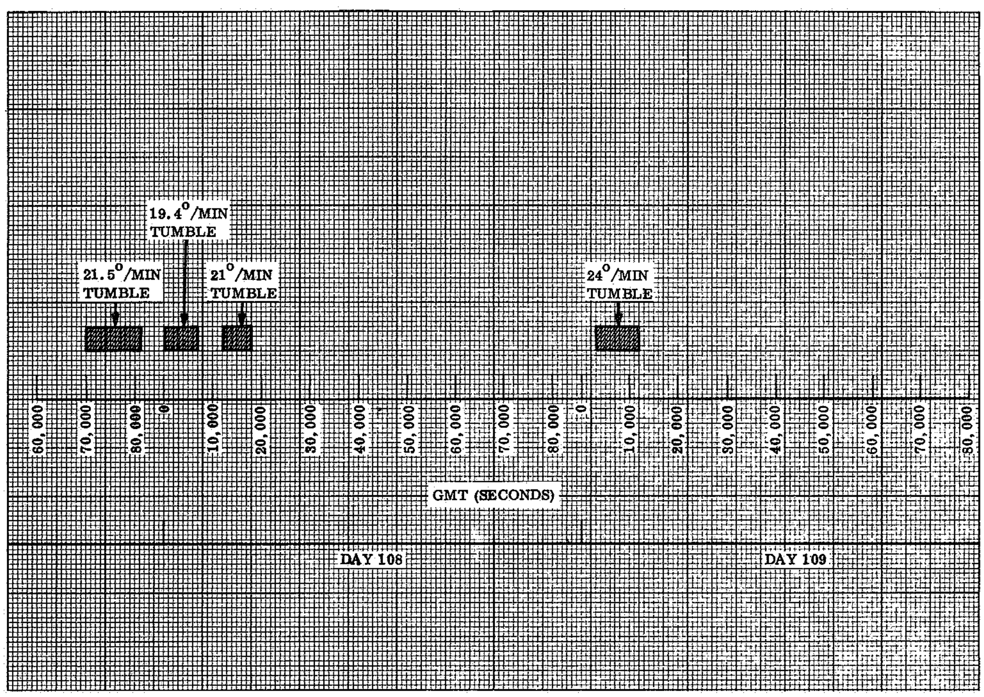
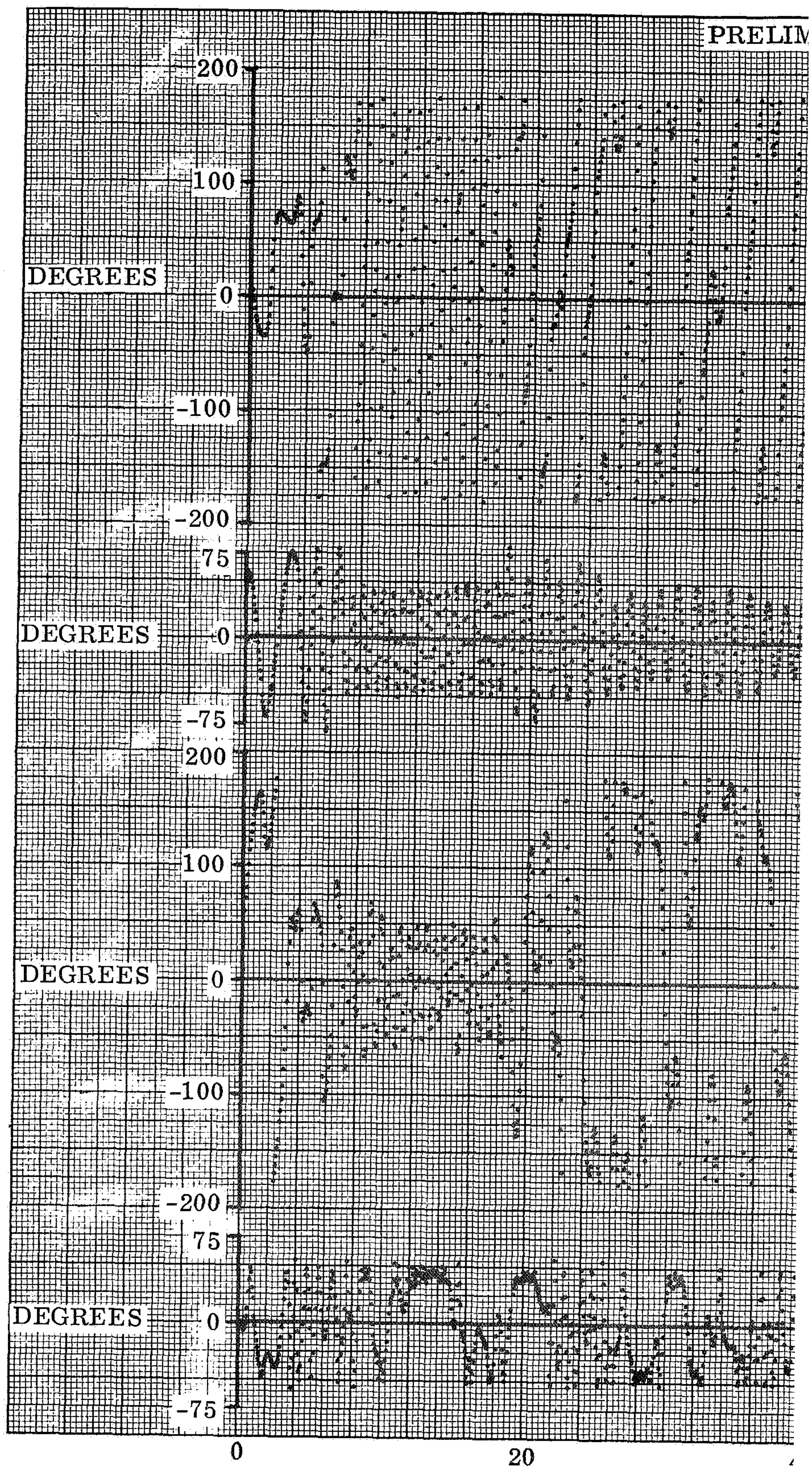


Figure 2–10. Indicated Attitude Performance Summary (Sheet 6)


PRELIM
200
100
DEGREES
0
-100
-200
75
DEGREES
0
-75
200
100
DEGREES
0
-100
-200
75
DEGREES
0
-75
0
20

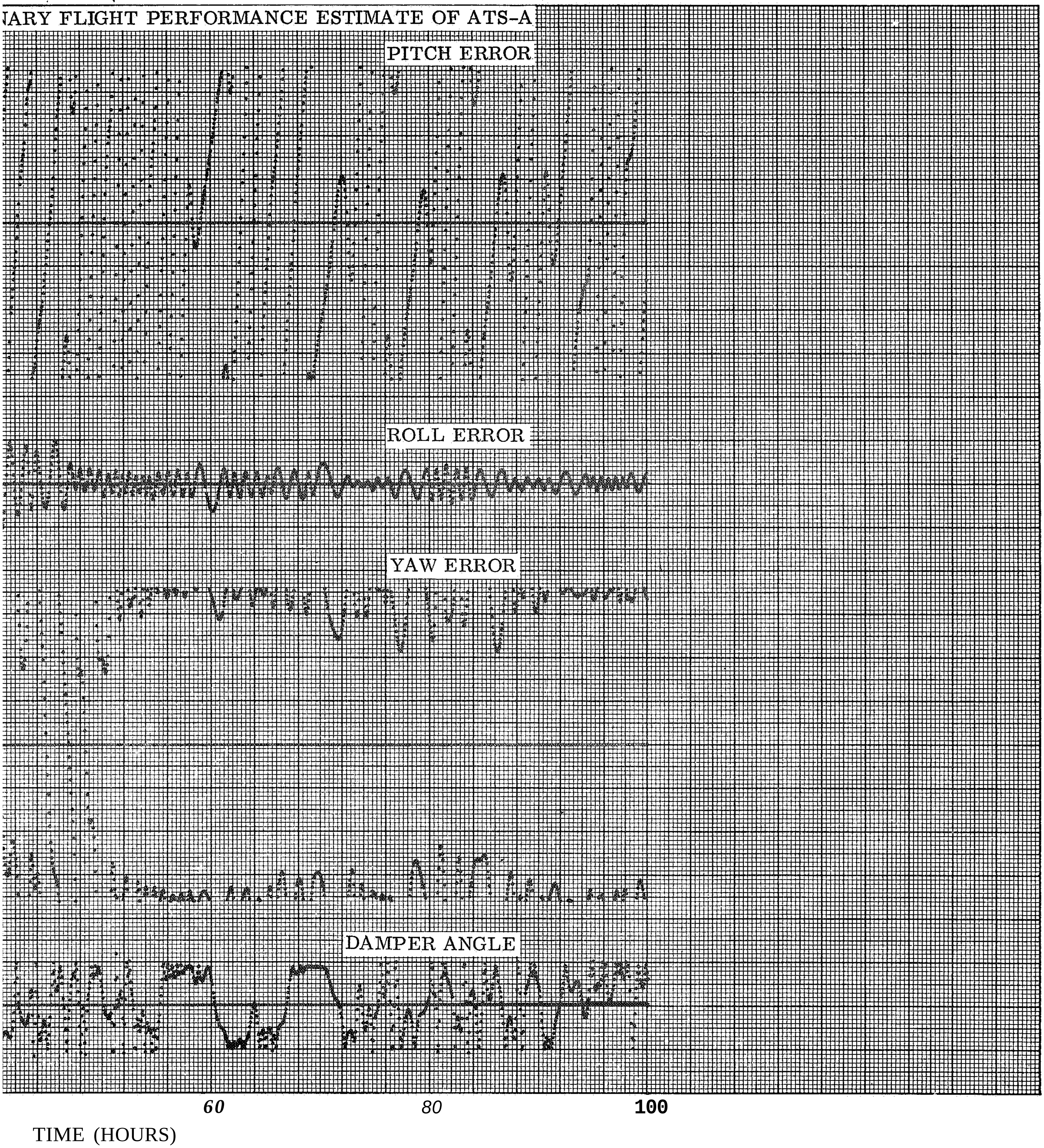


Figure 2-11. Preliminary Flight Performance Estimate of ATS-A

[redacted]

For the first 60 hours, the spacecraft is tumbling and oscillating heavily in all axes. The damper boom is free, however, and damping of the spacecraft's motions takes place. At approximately 60 hours, a tumble pattern is established in pitch, and oscillation pattern in roll. The presence of this pattern implies that a "steady state" condition has been reached (or nearly reached). Both roll and yaw have stabilized near the end of the run in spite of the pitch tumble. This is probably the result of the large rate of pitch tumble (0.15 deg/sec maximum) which tends to spin stabilize the spacecraft. The roll gravity gradient torques (which are effective in spite of the eccentricity) prevent the spin axis from wandering and create a "gyrocompassing" situation. As a consequence, yaw is also partially stabilized.

2.2.4 COMPONENT PERFORMANCE

All components of the gravity gradient system performed satisfactorily in contributing to system operation through the first 14 days of flight with the following exceptions:

a. Both earth sensor units exhibited an angular output when viewing cold space, and displayed a sensitivity to Television Camera System turn-on.

b. Over an isolated 18-minute period during Day 98, one channel of Solar Aspect Detector No. 5 produced a periodically intermittent output.

Most operating. characteristics fell well within expected range; none approached critical levels. A summary of the characteristics of all components is presented in Table 2-3.

2.2.4.1 Gravity Gradient System Booms

Primary boom system mechanisms and the damper boom deployment mechanism have performed nominally, and are exhibiting expected operating characteristics. The assembly and scissor motor temperatures indicated fall well within expected ranges, and the chamber pressure of each assembly is consistent with pre-launch conditions:

	Assembly A	Assembly B
Pre-launch:	10.2 psia	7.0 psia
In-orbits:	8.8-9.4 psia	6.4-6.7 psia

Table 2–3. Operating Characteristics Summary

Component	Function	Range: Expected	Range: Observed
Primary Boom System (Assembly A)	Assembly Temp	+32° to +143°F	+70° to +87°F
	Scissor Mtr Temp	+40° to +150°F	+70° to +82°F
	Pressure	5 to 9 psia	8.8 to 9.4 psia
Primary Boom System (Assembly B)	Assembly Temp	+32° to +143°F	68° to 91°F
	Scissor Mtr Temp	+40° to +150°F	70° to 81°F
	Pressure	5 to 9 psia	6.4 to 6.7 psia
Combination Passive Damper	Baseplate Temp	+20° to +110°F	+62° to +94°F
	Primary Weldment Temp	+20° to +110°F	+64° to +95°F
Power Control Unit	Unregulated Voltage	-24.3 to -32.0V	-29.2 to -30.8V
	Regulated Voltage	-23.5 to -24.5V	-24.5 to -24.9V
	Instrumentation Voltage	- 4.98 to - 5.02V	- 4.91 to - 5.04
Solar Aspect Sensor	Detector No. 1 Temp	-144° to +144°F	-111° to +115°F
	Detector No. 2 Temp	-25° to +115°F	+35° to +82°F
	Detector No. 3 Temp	-25° to +115°F	+38° to +66°F
	Detector No. 4 Temp	-25° to +115°F	+43° to +75°F
	Detector No. 5 Temp	-144° to +144°F	-78° to +107°F
	Control Unit Temp	+41° to +101°F	+76° to +85°F
Earth Sensor No. 1	Bolometer Temp	+50° to +90°F	+53° to +102°F
	Electronics Temp	+70° to +105°F	+59° to +142°F
Earth Sensor No. 2	Bolometer Temp	+50° to +90°F	+55° to +93°F
	Electronics Temp	+70° to +105°F	+59° to +134°F
TVCS No. 1	Vidicon Target Voltage	+250 to +350V	+290 to +300V
	Filament Current	+80 to +100 ma	+89.1 to +94.7 ma
	Faceplate Temp	+41° to +113°F	+60° to +95°F
	Electronics Temp	+69° to +136°F	+69° to +119°F
TVCS No. 2	Vidicon Target Voltage	+250 to +350V	+289 to +297V
	Filament Current	+80 to +100 ma	+87.3 to +89.6 ma
	Faceplate Temp	+37° to +111°F	+64° to +95°F
	Electronics Temp	+71° to +147°F	+66° to +161°F

Measured extension rates of the primary boom system assemblies during the initial deployment sequence were within **3.5%** of the average rates measured in ground testing (at a comparable voltage level), and fell at the midpoint of the specification tolerances:

Specified range = **1.2** ft/sec $\pm$ **0.3** ft/sec

Ground test rate: Assembly A = **1.8** ft/sec
Assembly B = **1.19** ft/sec

Flight performance rates: Assembly A = **1.22** ft/sec
Assembly B = **1.21** ft/sec

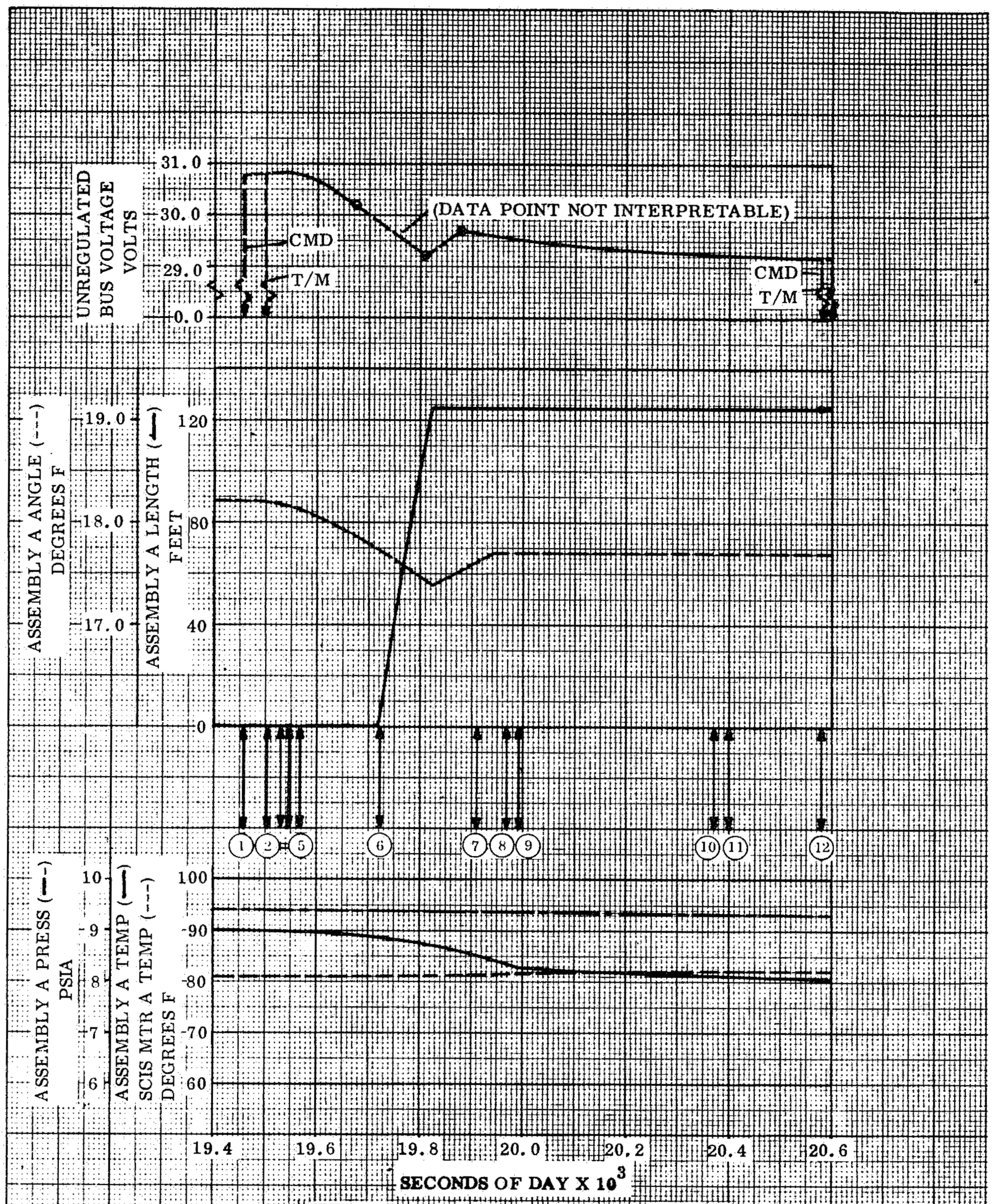
The boom extension profiles demonstrated were extremely smooth. The deployment sequence profiles for Assemblies A and B are presented in Figures **2-12** and **2-13,** respectively.

A shift in the scissor angle of both assemblies was indicated at the time of primary boom extension. This shift is consistent with the effect expected when the scissor bellows is permitted to react to the incurred reversal in pressure gradient:

		External		Internal		Gradient Condition
1)	pre-launch:	**14.7** psia	$\rightarrow$	**6-10** psia	=	positive gradient
2)	in-orbit:	0.0 psia	$\rightarrow$	**6-10** psia	=	negative gradient

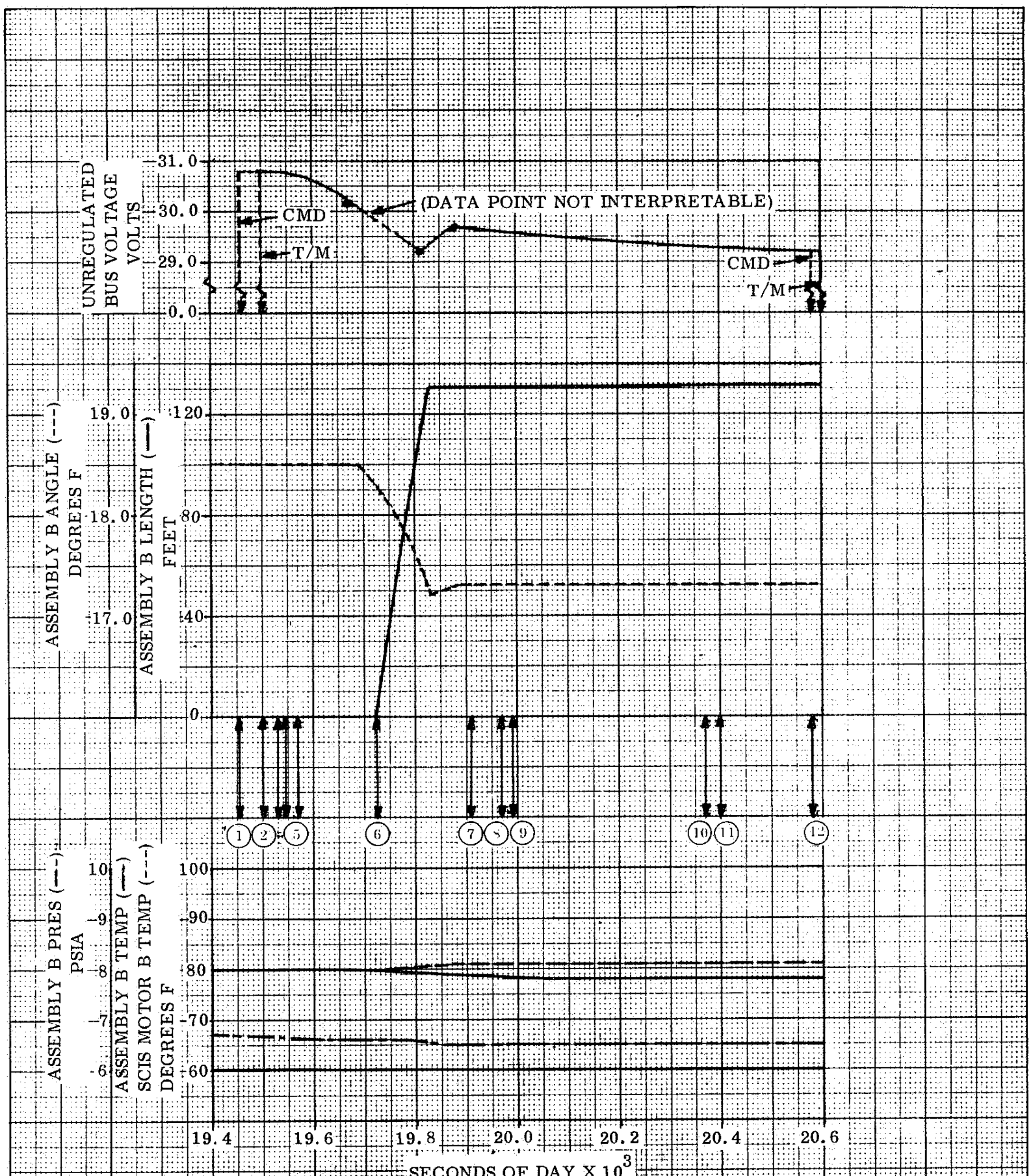
Damper boom extension appeared to occur as planned; observed freedom of damper motion indicates properly deployed booms. Although the damper boom release commands were executed several times **(F-11** executed twice, followed by **F-12),** there is no indication that the first command did not properly release the booms. Telemetry indication (received once per **92** seconds) indicated that release had been accomplished prior to transmission of the third release command **(F-13).**

Preliminary estimates of aero-bending moments felt at perigee on the gravity gradient system booms indicate that these effects of the flight orbit may be tolerated:



	ITEM	COMMAND SENT
1	PPS C ON	19455.0
2	FIRE BOOM A SQUIB 1	19501.0
3	FIRE BOOM B SQUIB 1	19531.0
4	FIRE BOOM A SQUIB 2	19546.0
5	FIRE BOOM B SQUIB 2	19567.0
6	MOTOR A/B EXTEND	19724.0
7	FIRE DAMPER BOOM SQUIB A	19911.0
8	FIRE DAMPER BOOM SQUIB A	19970.0
9	FIRE DAMPER BOOM SQUIB B	19986.0
10	FIRE DAMPER SQUIB A	20372.0
11	FIRE DAMPER SQUIB B	20402.0
12	PPS C OFF	20581.0

Figure 2-12. Boom Deployment Profile - Assembly **A**



	ITEM	COMMAND SENT
1	PPS C ON	19455.0
2	FIRE BOOM A SQUIB 1	19501.0
3	FIRE BOOM B SQUIB 1	19531.0
4	FIRE BOOM A SQUIB 2	19546.0
5	FIRE BOOM B SQUIB 2	19567.0
6	MOTOR A/B EXTEND	19724.0
7	FIRE DAMPER BOOM SQUIB A	19911.0
8	FIRE DAMPER BOOM SQUIB A	19970.0
9	FIRE DAMPER BOOM SQUIB B	19986.0
10	FIRE DAMPER SQUIB A	20372.0
11	FIRE DAMPER SQUIB B	20402.0
12	PPS C OFF	20581.0

Figure 2-13. Boom Deployment Profile - Assembly B

Maximum tolerable bending moment = 10 in-lb.

Estimated maximum bending moment (due to aerodynamic loading $\cong$ 3 in-lb.

The primary boom system has not been commanded, except for initial deployment, during the first 14 days of flight.

High frequency components of boom dynamics have been observed on television data. Attitude sensor data from Days 102 through 109 has indicated that the spacecraft motion has similar high frequency components. A discussion of observed boom dynamics is presented in Section 2.4.

2.2.4.2 Combination Passive Damper

Combination Passive Damper monitors indicate proper operation in consideration of the flight orbit. Both baseplate and primary weldment temperatures fall well within expected ranges throughout the first 14 days of flight. Observed motion of the damper boom confirms that proper uncaging occurred, and is consistent with telemetry indications of uncaging. Both damper uncage squib commands (F-15, F-16) were executed during the initial deployment sequency; as no "damper release" telemetry monitor sampling occurred between the first and second commands (one sample/92 sec), either may have initiated the uncaging event. However, there is no indication that either command did not execute properly. Performance of the Damper Boom Angle Indicator appears nominal; both lamp filaments No. 1 and No. 2 have been used through the first 14 days of flight.

Observed motion of the damper boom indicates large damper boom oscillations with indications of some lateral shifting of the damper "hinge" axis. First indication of maximum excursions occurred at 71,000 seconds of Day 96 (19:32:06 GMT), approximately 14 hours after separation. The highest observed impact velocity of the damper booms against the damper boom stops for the first 14 days of flight occurred at 80,860 and 81,060 seconds of Day 96 (22:27:40 and 22:31:00 GMT, respectively). In both cases, the damper boom angular velocity was 40 degrees per minute.

Although some lateral shifting of the damper "hinge" axis has been observed throughout the 14 days of flight, there is no evidence that the eddy-current damper diamagnetic suspension is not functioning properly. Observed motion of the damper boom indicates that the damper boom shaft is free of any obstruction to motion.

Since spacecraft libration damping has been provided by the eddy-current damper throughout the first 14 days of flight, the CPD clutching mechanism and the Passive Hysteresis Damper have not been exercised.

2.2.4.3 Power Control Unit

During the first 14 days of flight, a total of 445 gravity gradient commands have been transmitted to the spacecraft (see Table 2-4). All but 48 of the commands have been confirmed as properly executed. Out of the 48 unconfirmed commands, 28 could not be confirmed due to lack of data, and 13 could not be confirmed because they were improperly sequenced. Three "All Sensors Off" commands were transmitted, but did not turn off the attitude sensors since the unregulated power was not turned on prior to the transmission of the "All Sensors Off" commands. The remaining nine commands attempted to turn On a sensor that was already on, or turn Off a sensor that was already off.

Seven gravity gradient commands failed to be properly executed.

a. At 3900 seconds of Day 98, TVCS Sys. 1 OFF command was transmitted. Data shows that TVCS Sys. 1 remained On. At 3955 seconds, the same command was retransmitted and data shows that TVCS Sys. 1 turned Off at 3956.1 seconds.

b. SAS and Angle Det. B and SAS Angle Det. C commands were transmitted at 81320 and 81340 second, respectively, of Day 100. Flight data shows that the two commands failed to turn the Solar Aspect Sensor and Angle Indicator On. The commands were repeated at 82025 and 82050 seconds respectively, and flight data verified proper execution at 82052 seconds.

c. SAS and Angle Det. B and SAS and Angle Det. C commands were transmitted at 18675 and 18725 seconds, respectively, of Day 101. Flight data shows that the two commands failed to turn the Solar Aspect Sensor and Angle Indicator On. The commands were repeated at 18790 and 18815 seconds, respectively, and flight data verified proper execution at 18816 seconds.

d. At 19025 seconds of Day 109, IR Earth Sensor 1 ON command was transmitted. Flight data shows that IR Earth Sensor 1 remained Off. The same command was retransmitted at 19085 seconds and flight data shows that IR Earth Sensor 1 was turned On at 19086 seconds.

e. At 77700 seconds of Day 109, IR earth Sensor 1 OFF command was transmitted. Data shows that IR Earth Sensor 1 remained On.

An investigation of the improperly executed commands is underway.

Table 2-4. Gravity Gradient Commands Transmitted to Spacecraft

ITEM	COMMAND NAME	NO. OF TRANSMISSIONS
F-1	TVCS 1 ON	47
F-2	TVCS 1 OFF	47
F-3	TVCS 2 ON	39
F-4	TVCS 2 OFF	40
F-5	Earth Sensor 1 ON	47
F-6	Earth Sensor 1 OFF	45
F-7	Earth Sensor 2 ON	46
F-8	Earth Sensor 2 OFF	46
F-9	SAS and Angle Det. A	4
F-10	SAS and Angle Det. B	29
F-11	Fire Damper Boom Squib Driver A	2
F-12	Fire Damper Boom Squib Driver B	1
F-13	SAS and Angle Det. C	20
F-14	SAS and Angle Det. D	20
F-15	Fire Damper Uncage Squibs Driver A	1
F-16	Fire Damper Uncage Squibs Driver B	1
F-21	Fire Primary Boom Assy. A Squib 2	1
F-22	Fire Primary Boom Assy. A Squib 1	1
F-23	Fire Primary Boom Assy. B Squib 2	1
F-24	Fire Primary Boom Assy. B Squib 1	1
F-30	Rod, Motor A and B EXTEND	1
F-41	Payload Power Switch C ON	1
F-42	Payload Power Switch C OFF	1
F-45	All Sensors OFF	3

Both the Regulated Bus Voltage and Instrumentation Voltage have exceeded expected limits. The Regulated Bus Voltage has been observed to vary between -24.5 and -24.9 vdc which is above the expected range (-23.5 to -24.5 vdc). The Instrumentation Voltage has ranged from -4.91 vdc to -5.04 vdc. Both extremes are outside the expected range (-4.99 to -5.01 vdc). The cause of the out-of-limit readings is currently being investigated.

The Unregulated Bus Voltage, when turned On only during the early portion of flight, was observed to be well within the expected range.

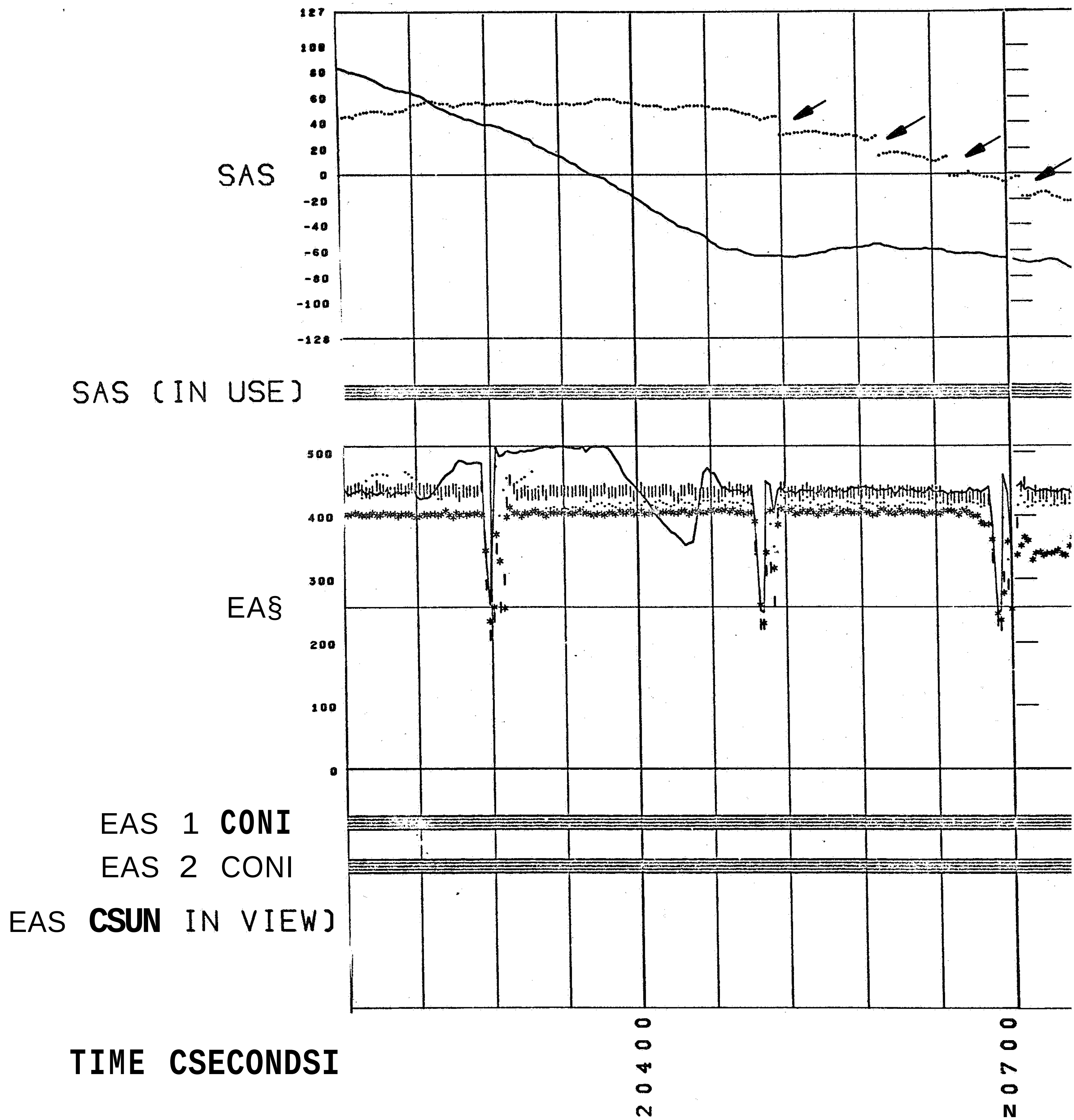
2.2.4.4 Solar Aspect Sensor

The Solar Aspect Sensor has performed nominally throughout the first 14 days of flight with the following exceptions:

a. Between 20,500 and 21,540 seconds (05:41:41-05:59:00 GMT) of Day 98, data received from the Angle A channel of detector 5 (presented in Figure 2-14) contained periodic shifts of eight-count magnitude (four degrees). These shifts were observed over a range of counts from +50 to -90 counts (+25 to -45°). Data from the Angle B channel remained continuous through this time period. Several subsequent occurrences of this characteristic have appeared. (Analysis of this data is presently underway.)

b. Between 55,200 and 58,000 seconds (15:20:00-16:06:40 GMT) of Day 98, detector identification (see Figure 2-15) indicates that the spacecraft is in a solar eclipse condition (no detector illuminated). Examination of the Angle A and Angle B channels shows that the spacecraft is in view of the sun and in fact, clearly indicates several transitions between detectors. Between 58,000 and 58,890 seconds (16:06:40 - 16:21:30 GMT) of the same day, detector 2 was identified as the most illuminated. Angle A and Angle B data for the same time period shows a transition to some other detector for approximately 3 minutes. (Analysis of this problem is presently underway.)

c. Between 25,740 and 29,580 seconds (07:09:00 - 08:13:00 GMT) of Day 102, Angle B channel contained periodic shift (see Figure 2-16) of varying magnitudes and polarity (some as large as 40 degrees), while the Angle A channel output oscillated (10 degrees peak-to-peak) about -43 degrees early in this time period. The Angle A channel output eventually settled to a constant value of -43 degrees. A detector generates an output of -43 degrees when no sun is visible. All five detectors were identified as most illuminated at various times during this period. (Analysis of this data is underway).



SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS (IN USE)
EAS
500
400
300
200
100
0
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
TIME (SECONDS)
20400
20700

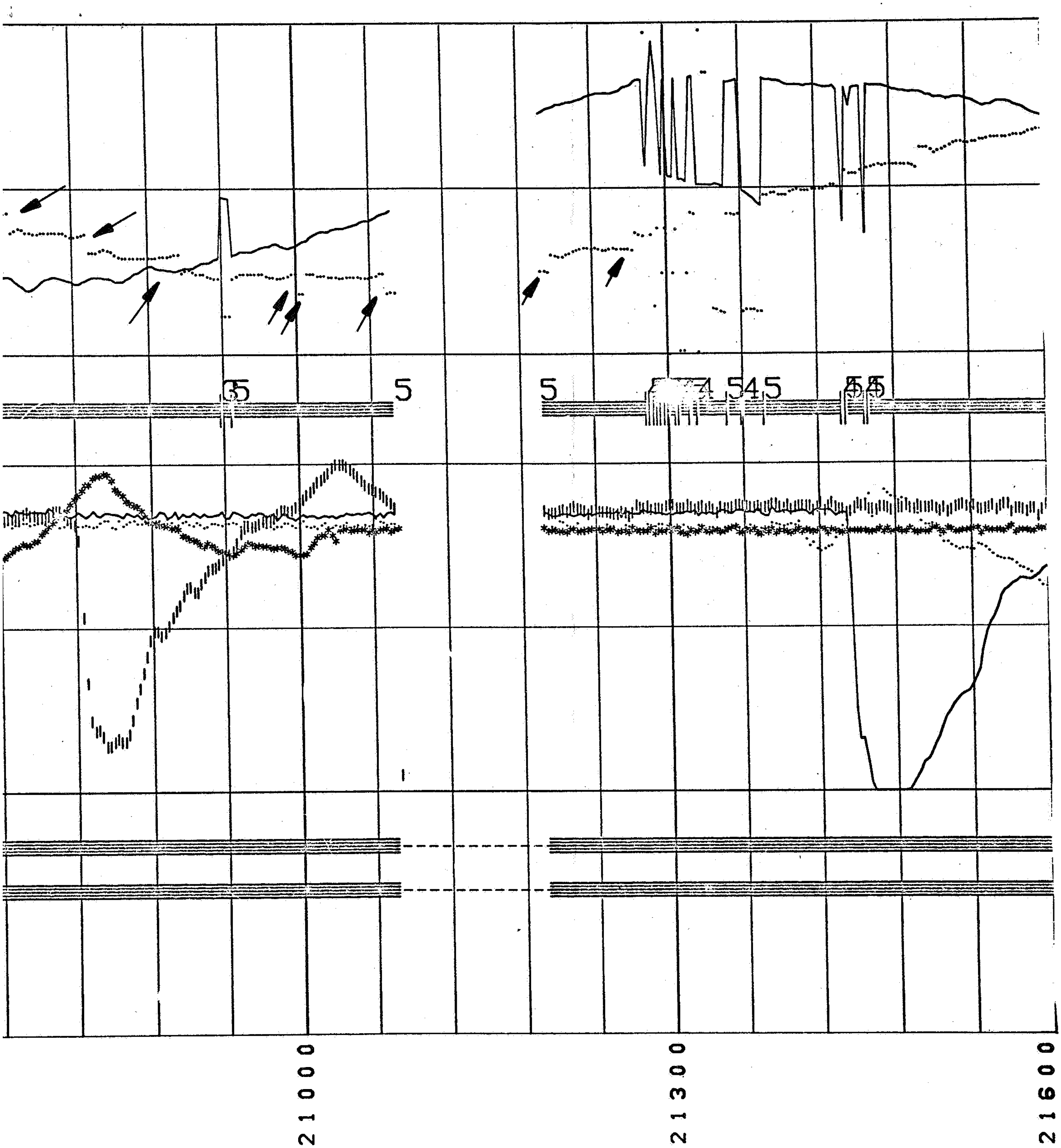
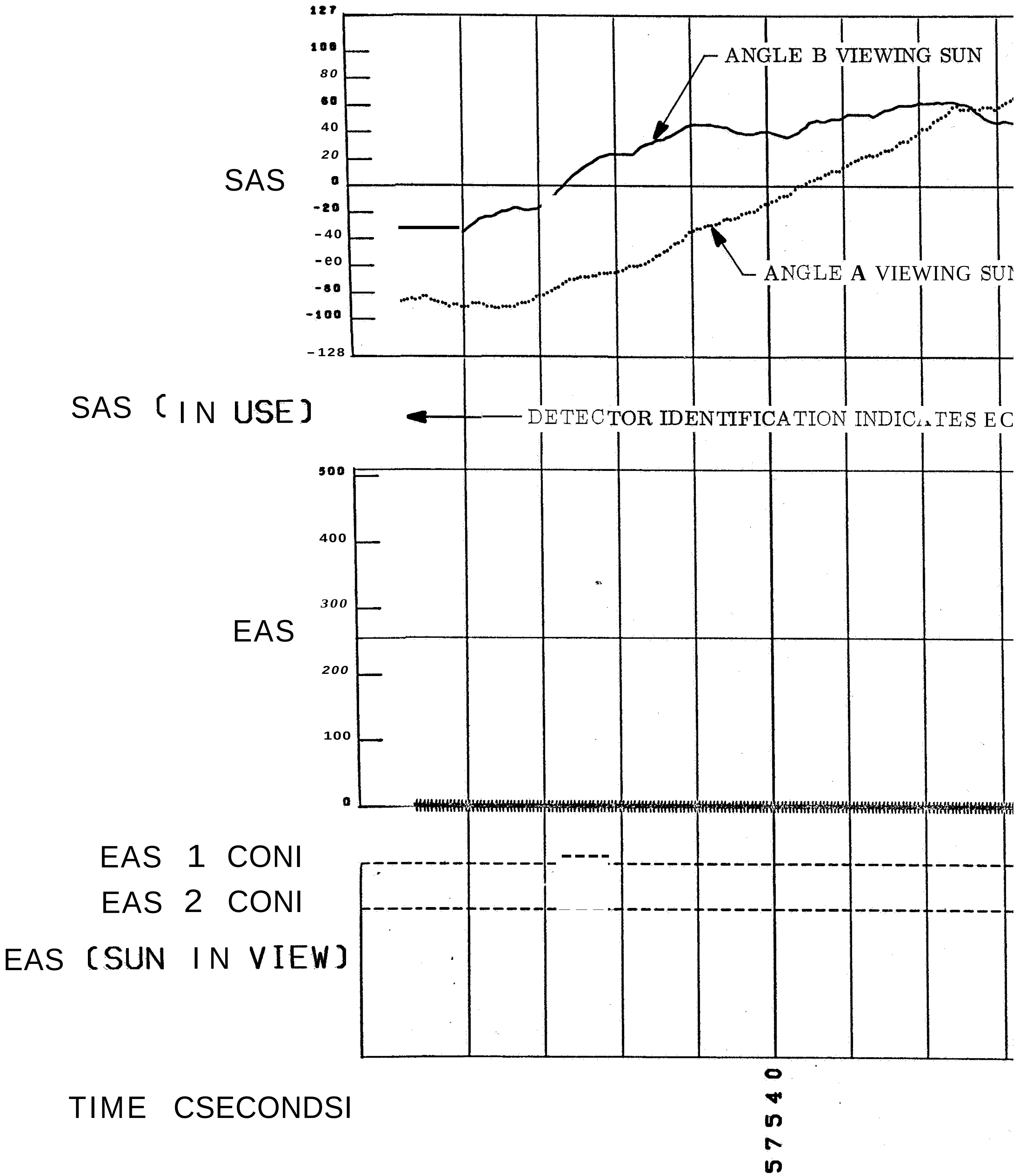
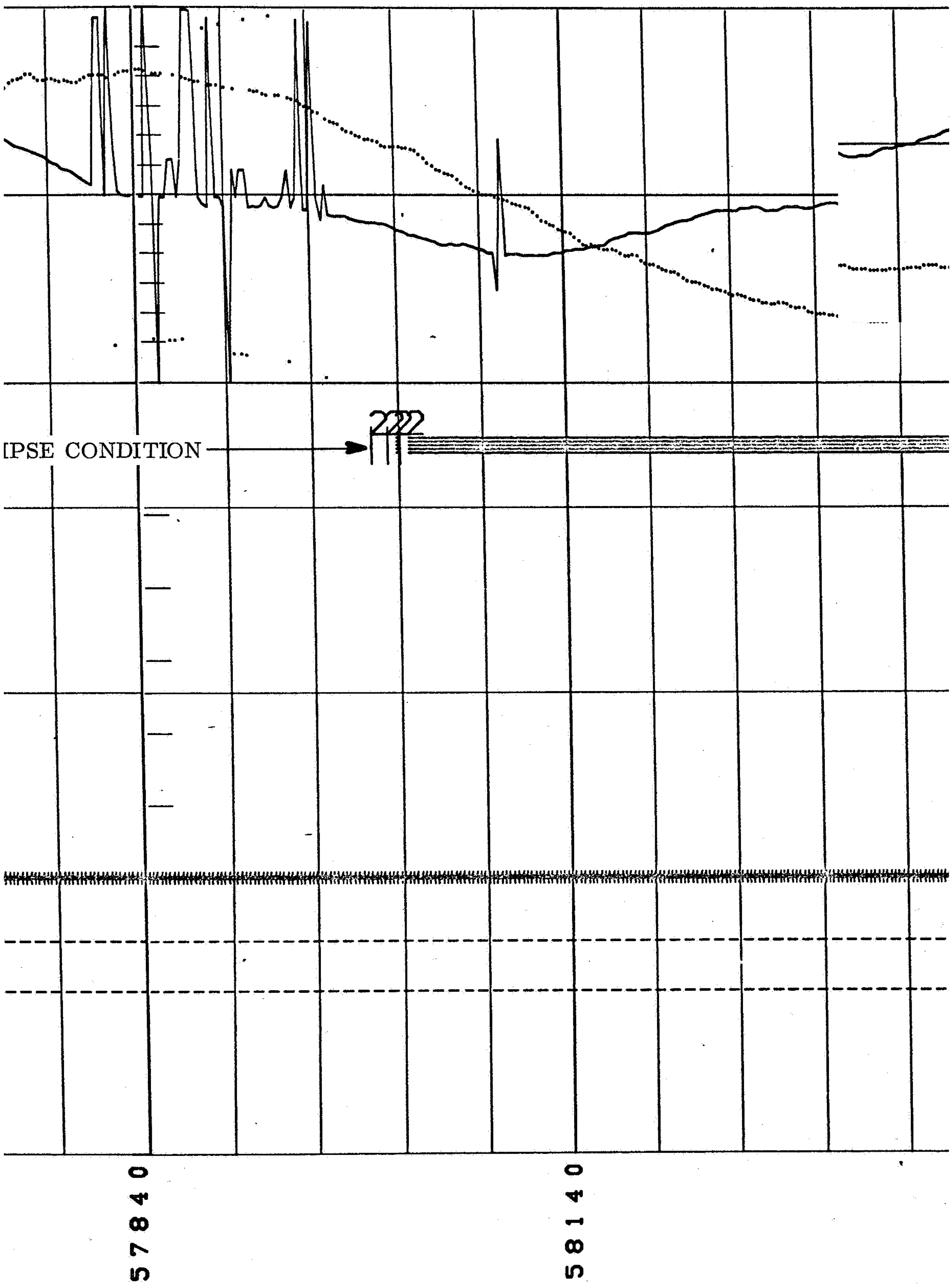


Figure **2-14.** Solar Aspect Sensor Data - Day **98**


127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS
ANGLE B VIEWING SUN
ANGLE A VIEWING SU
SAS (IN USE)
DETECTOR IDENTIFICATION INDIC TES EC
500
400
300
200
100
0
EAS
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
TIME (SECONDS)
57540


IPSE CONDITION
57840
58140

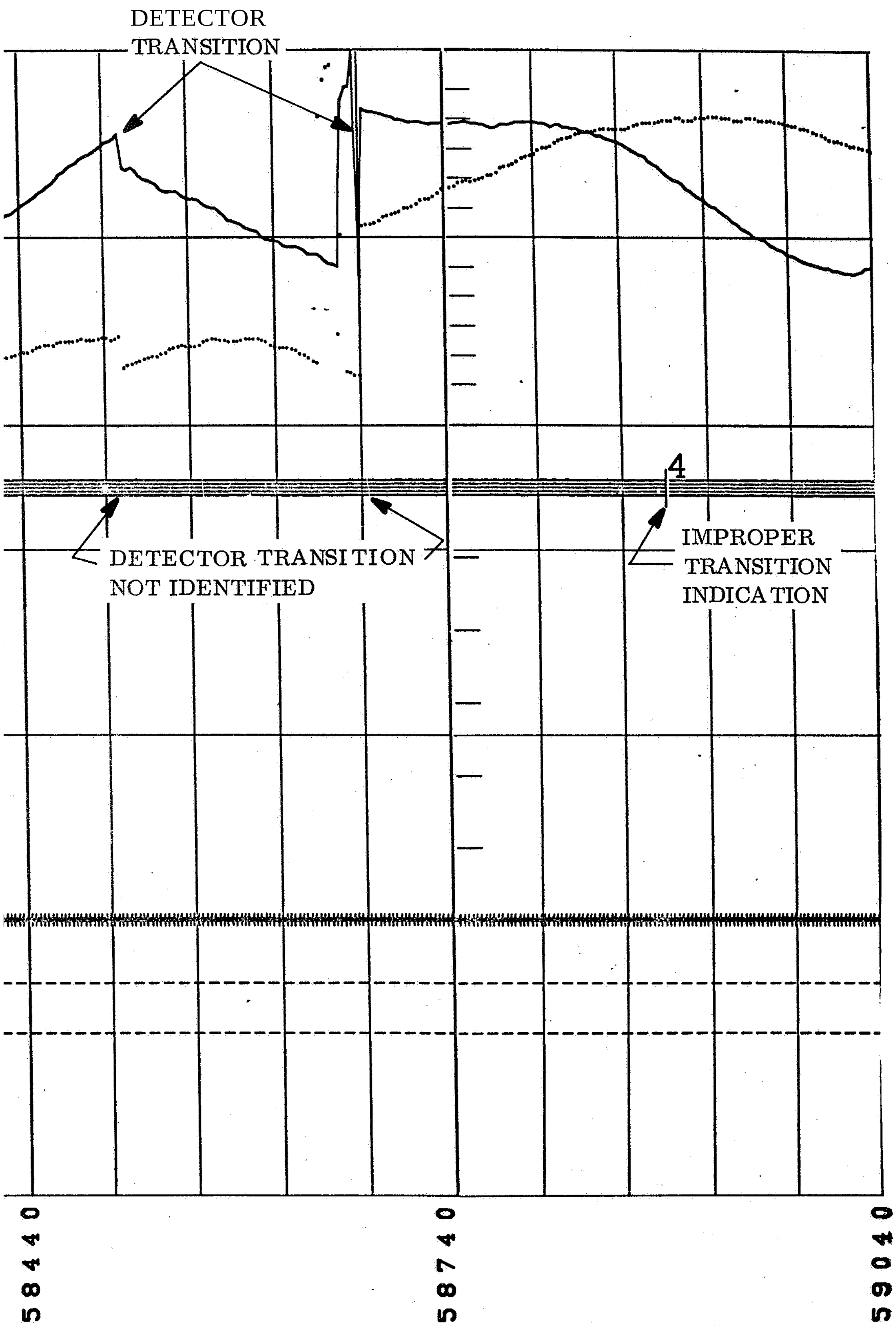
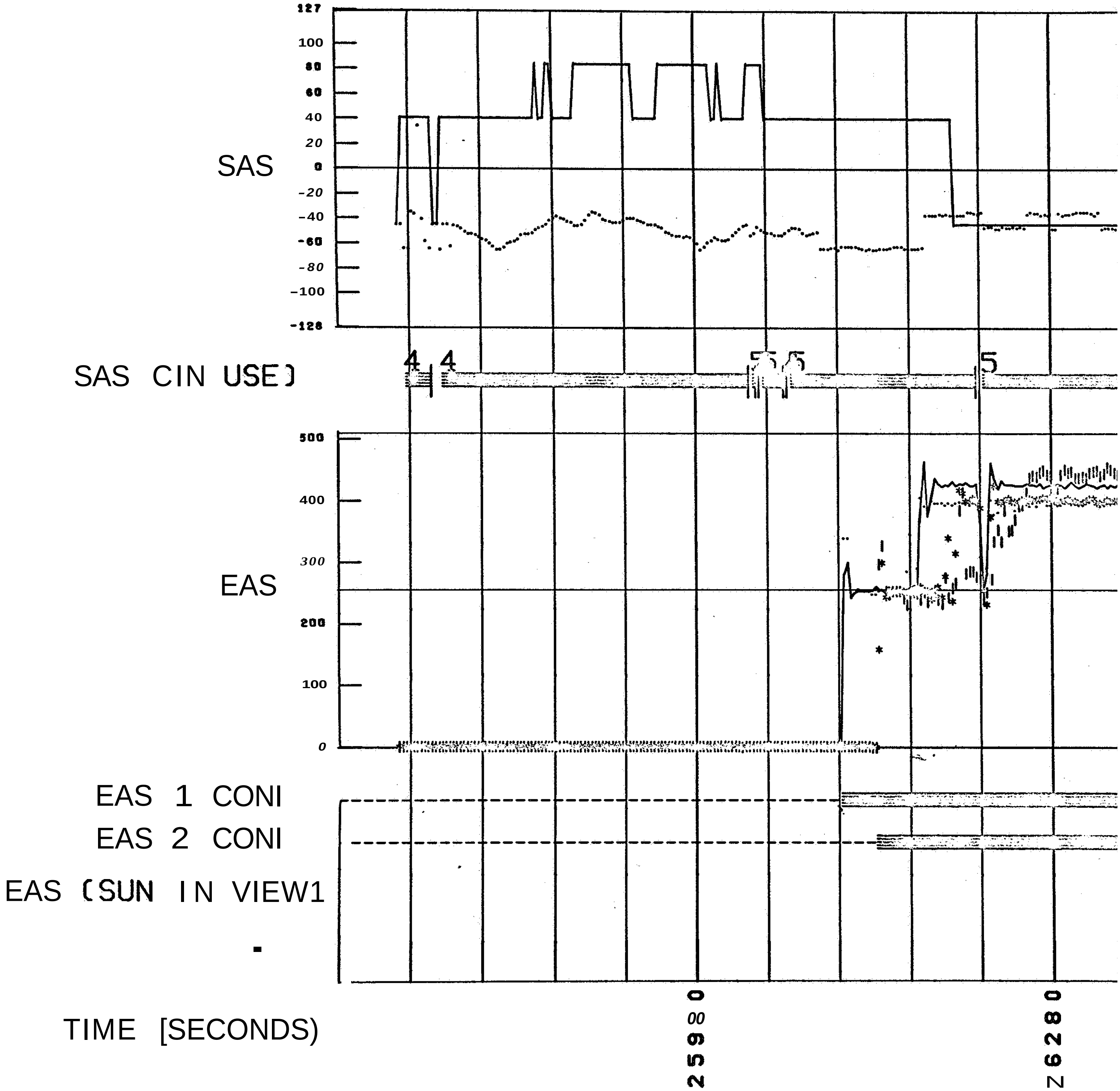
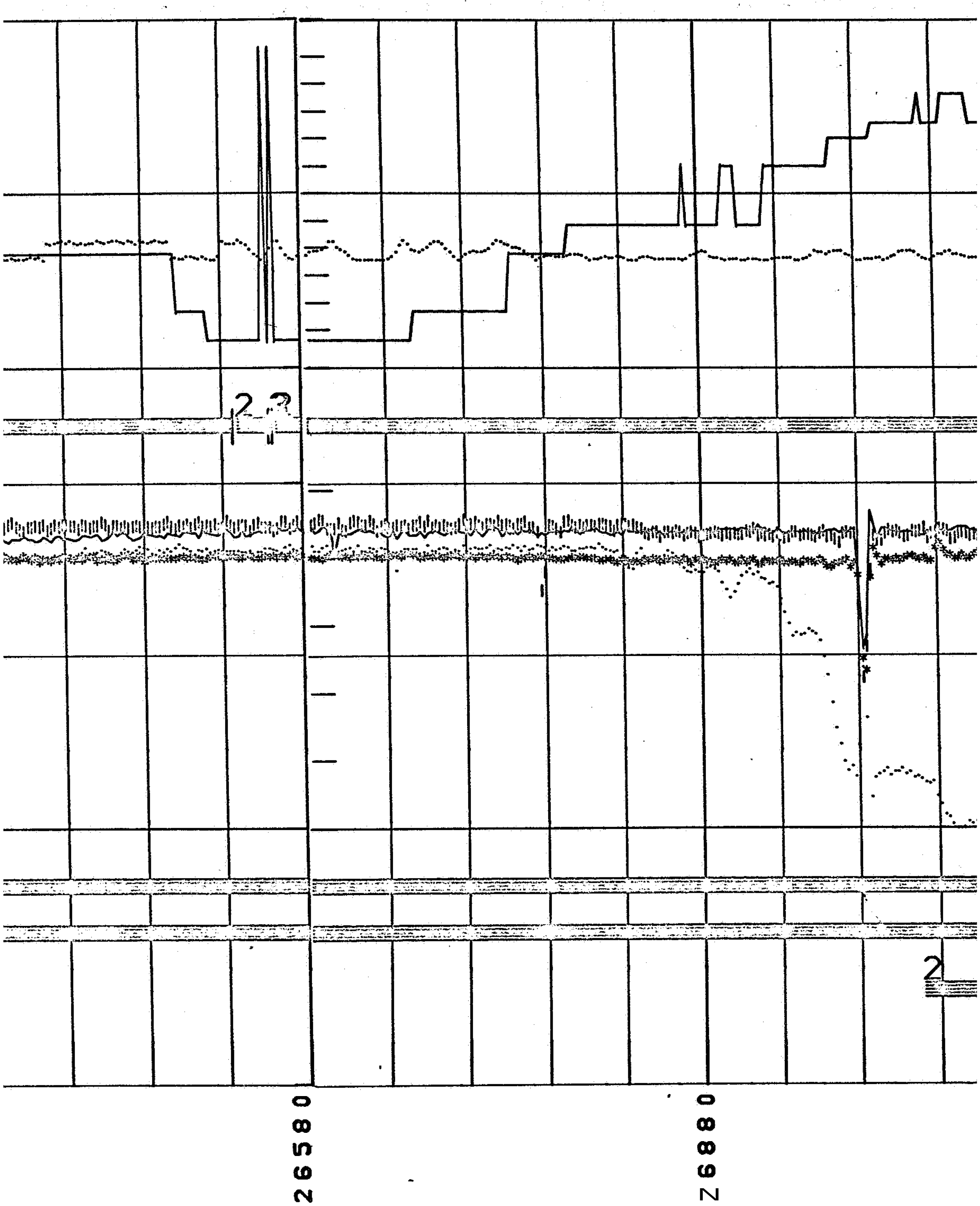


Figure 2-15. **Solar Aspect** Sensor Data -
Day 98


SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS CIN USE]
4
4
5
EAS
500
400
300
200
100
0
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW1
TIME [SECONDS)
25900
26280



2-58-1

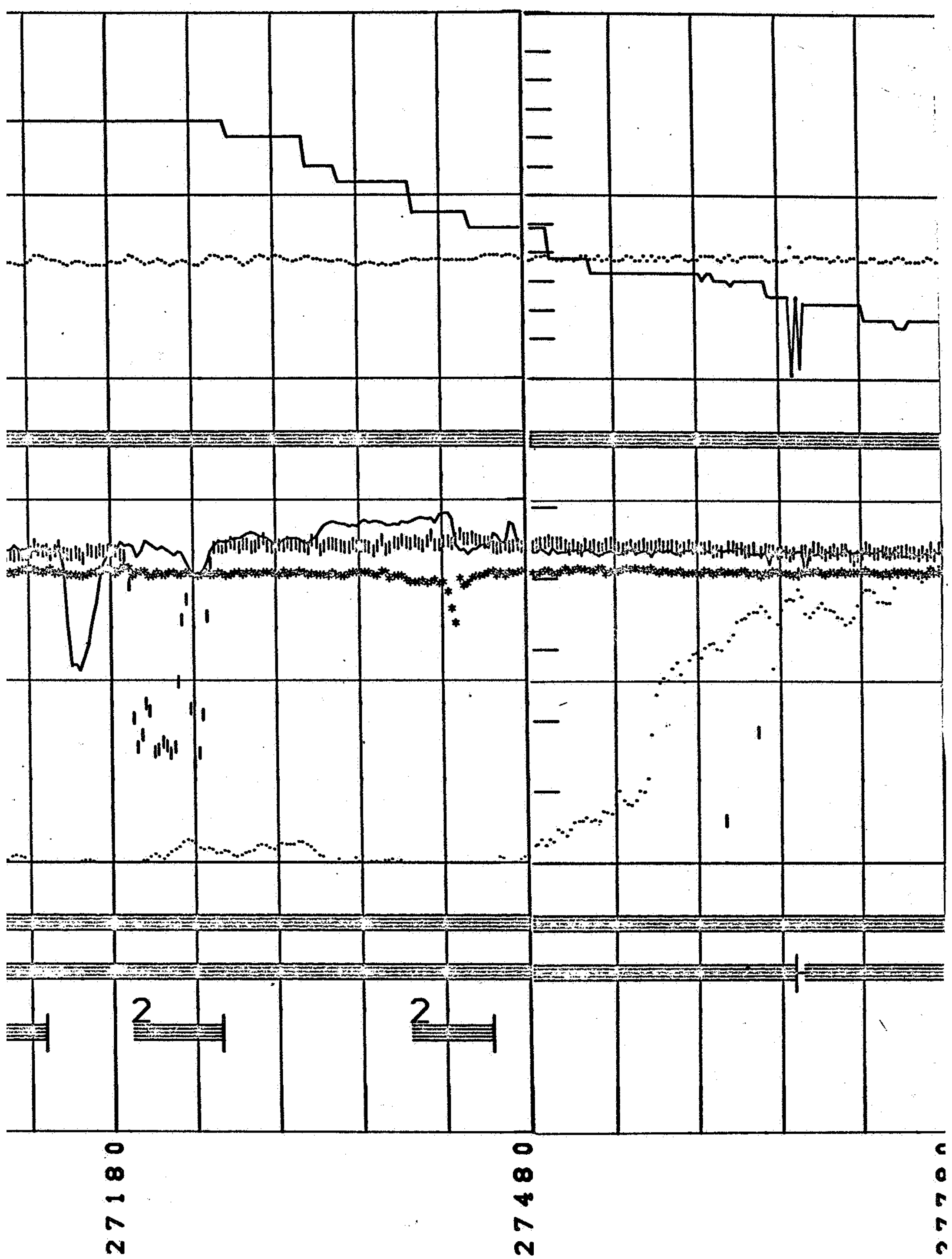


Figure 2-16. Solar Aspect Sensor Data -
Day 102

2.2.4.5 Earth Sensors

The performance of both Earth Sensor units has appeared to be normal when within range of the earth, but is seriously qualified by the presence of an unexpected bias on the outputs of any scan axis not within range of the earth. Measurements during the period of flight immediately preceding separation (see Figure 2-1) indicated expected orientation of the spacecraft under Agena attitude control as measured by Earth Sensor No. 1, but also exhibited an off-null output from Earth Sensor No. 2, which would have been viewing space. Subsequent data throughout flight has consistently confirmed this apparent presence of radiation, independent of spacecraft attitude, when out of range of the earth. Some variation has been noted in the average value of the bias at various axes, but has not been correlated with any characteristic of orbital flight, apparent attitude, or solar incidence condition. Examination of flight data has resulted in determination of several characteristics of sensor operation:

a. Cases of entry into or exit from the bias level on all axes have exhibited both discontinuous and continuous transitions. A tangential approach toward the earth by an axis has been expected to produce apparent discontinuity in data, and may explain discontinuous data when observed: however, the lack of discontinuity existing in many of the space-earth transitions observed suggests that earth-within-range measurements may also be biased in some way.

b. Sudden shifts in measurement rate-of-charge have been noted on all sensor axes. These may be attributed to sudden changes in vehicle attitude, but may also be caused by scale factor changes inherent in sensor performance. Certain scale factor changes of this type are expected, but in many instances the output value at which these shifts take place are at points either than those where normal shifts would take place.

c. Both sensors have exhibited an unexpected sensitivity to turn-on of either Television Camera System. This sensitivity has been indicated by an output transient towards a (normal) null reading of 0°, or -2.56 volts, and has been observed under both "earth-present" and "earth-absent" conditions.

Preliminary testing of the engineering model earth sensor unit at GSFC has verified a biased output from the sensor scan axes when viewing an extremely cold (-320°F) uniform surface, and a normal output when viewing an ambient (70°F) uniform surface (within a vacuum). Further testing is being planned to determine the consistency or variation in sensor calibration when viewing a radiating target against a cold background.

Preliminary studies are presently underway to determine the feasibility of reconstructing sensor calibration curves from flight data.

Electronics and bolometer temperatures of both units in flight have remained in agreement with system test data. Neither temperature on either sensor has been observed to approach critical levels.

Examples of sensor performance characteristics are presented in Figures 2-17 through 2-21.

2.2.4.6 Television Camera System

Both Television Camera Systems were in operation during the first 13 days of flight. Both systems have performed nominally. Target voltage and filament current in each system were nominal, and faceplate temperature measured on each system has remained well within expected limits. The electronics temperature of Television Camera System No. 2 rose above the expected maximum (147°F) to 161°F. This is, however, well below the critical level (200°F). The electronics temperature on system No. 1 remained within its expected range.

Visual examination of video received from each system indicated that both are performing normally. The reticle marks are visible in both cameras and are of better quality against a space background than an earth-image background (as expected). The resolution and contrast characteristics of both systems are comparable to those observed during ground testing.

2.2.5 DATA INVENTORY

The ATS-2 flight performance data discussed in this report consists of telemetry and antenna polarization measurement data provided to General Electric on magnetic tapes. The time intervals through the first 14 days of flight for which recorded data has been received are presented in Figure 2-22.

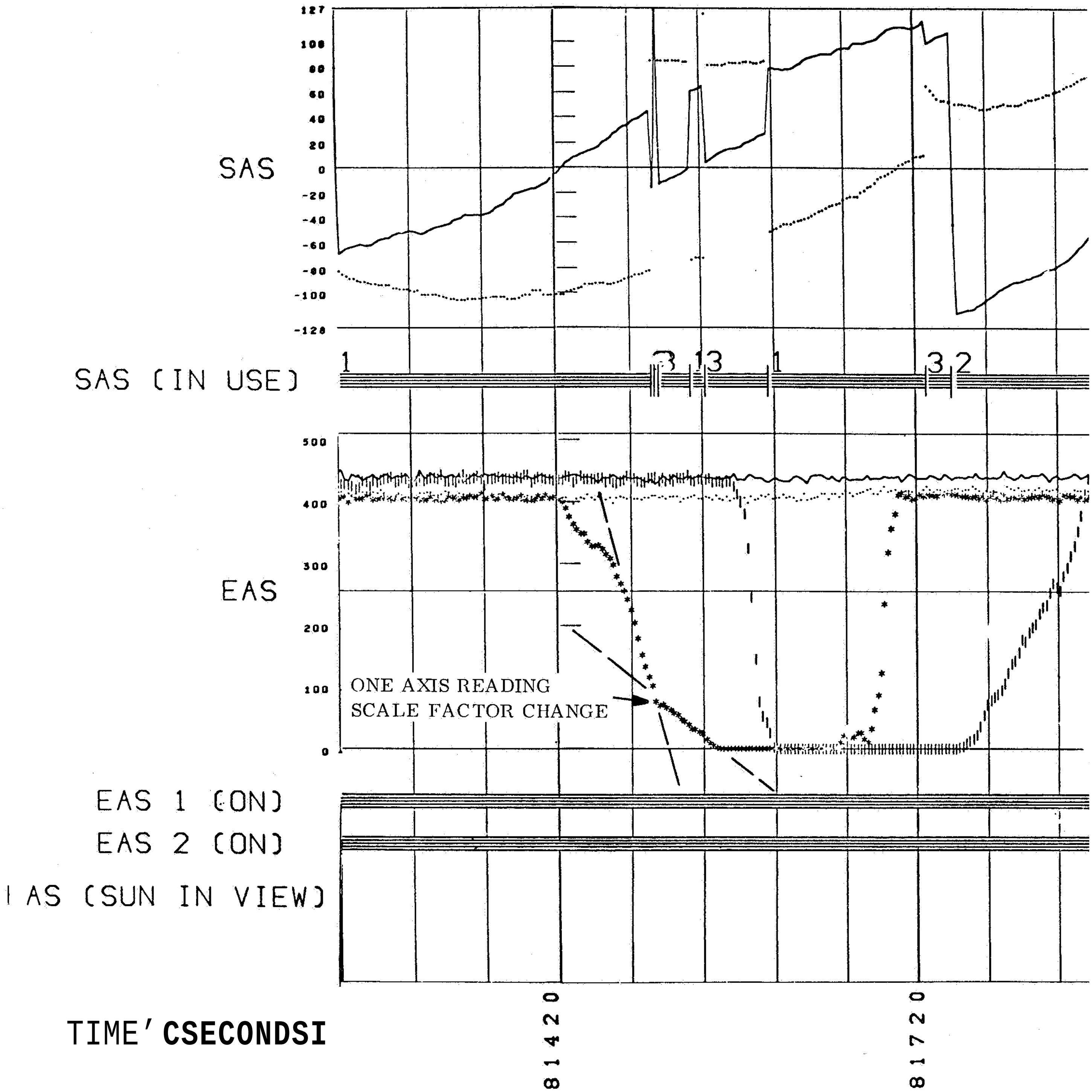


Figure 2-17. Earth Sensor Data (1) - Day 97

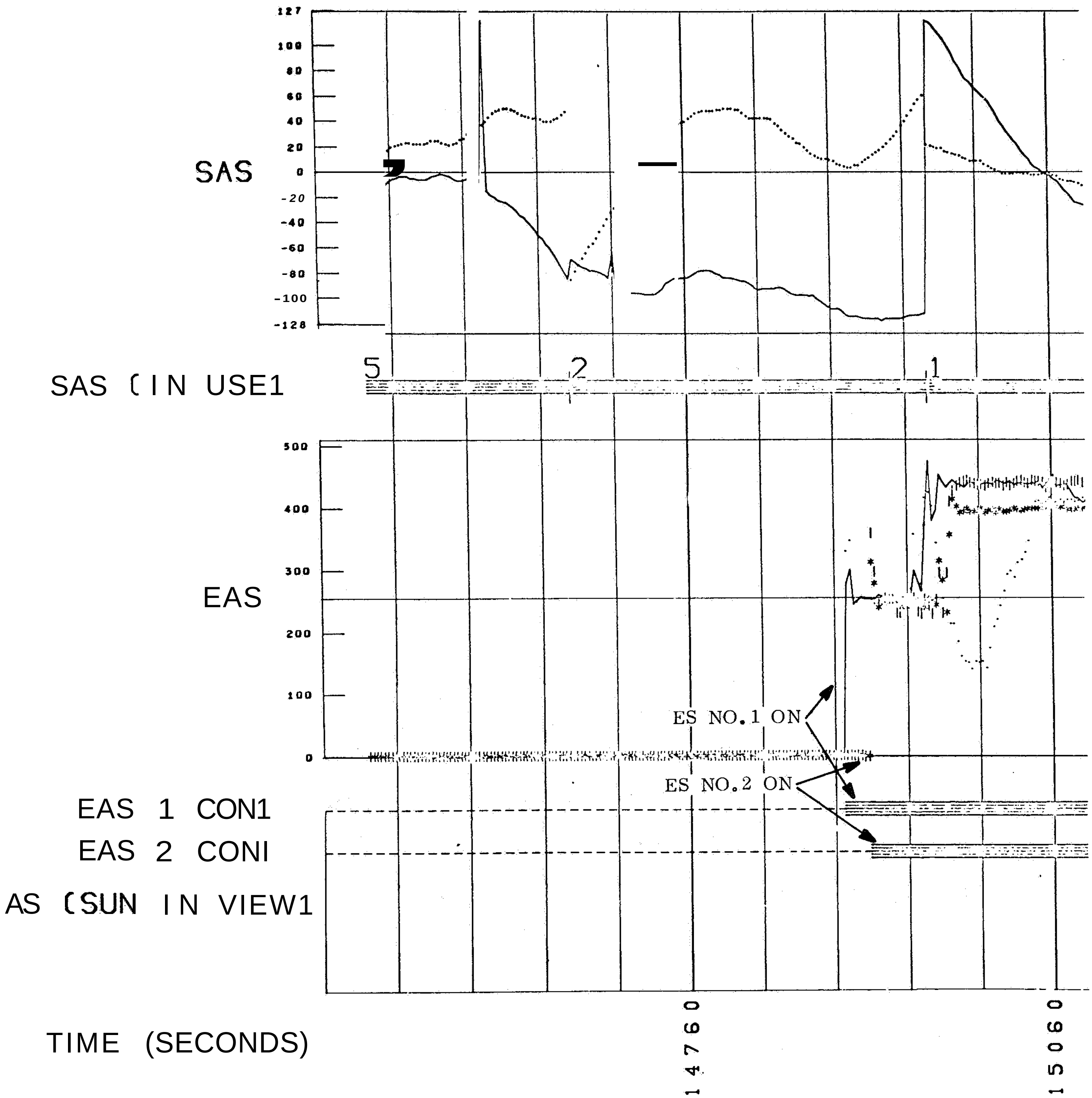
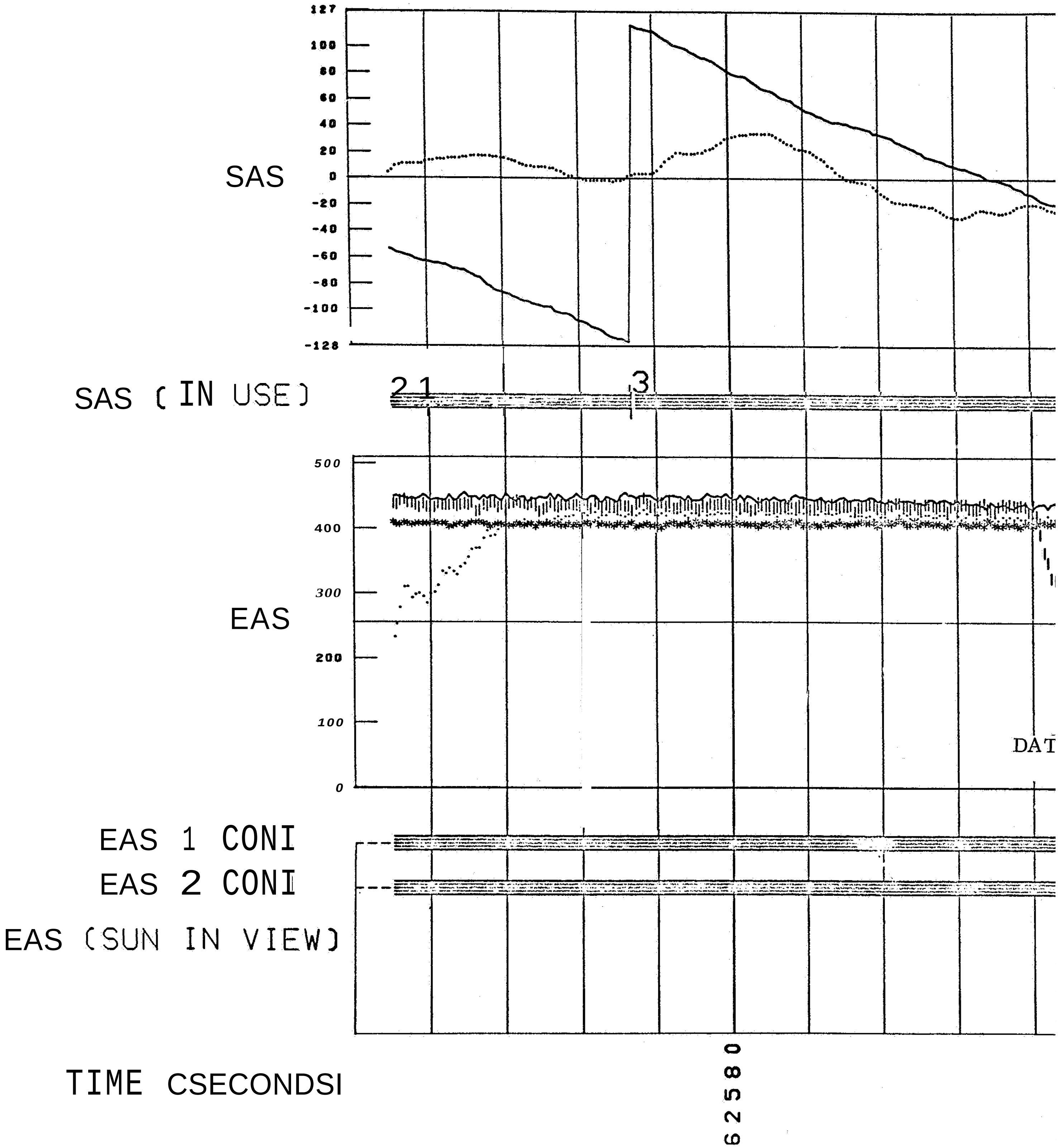
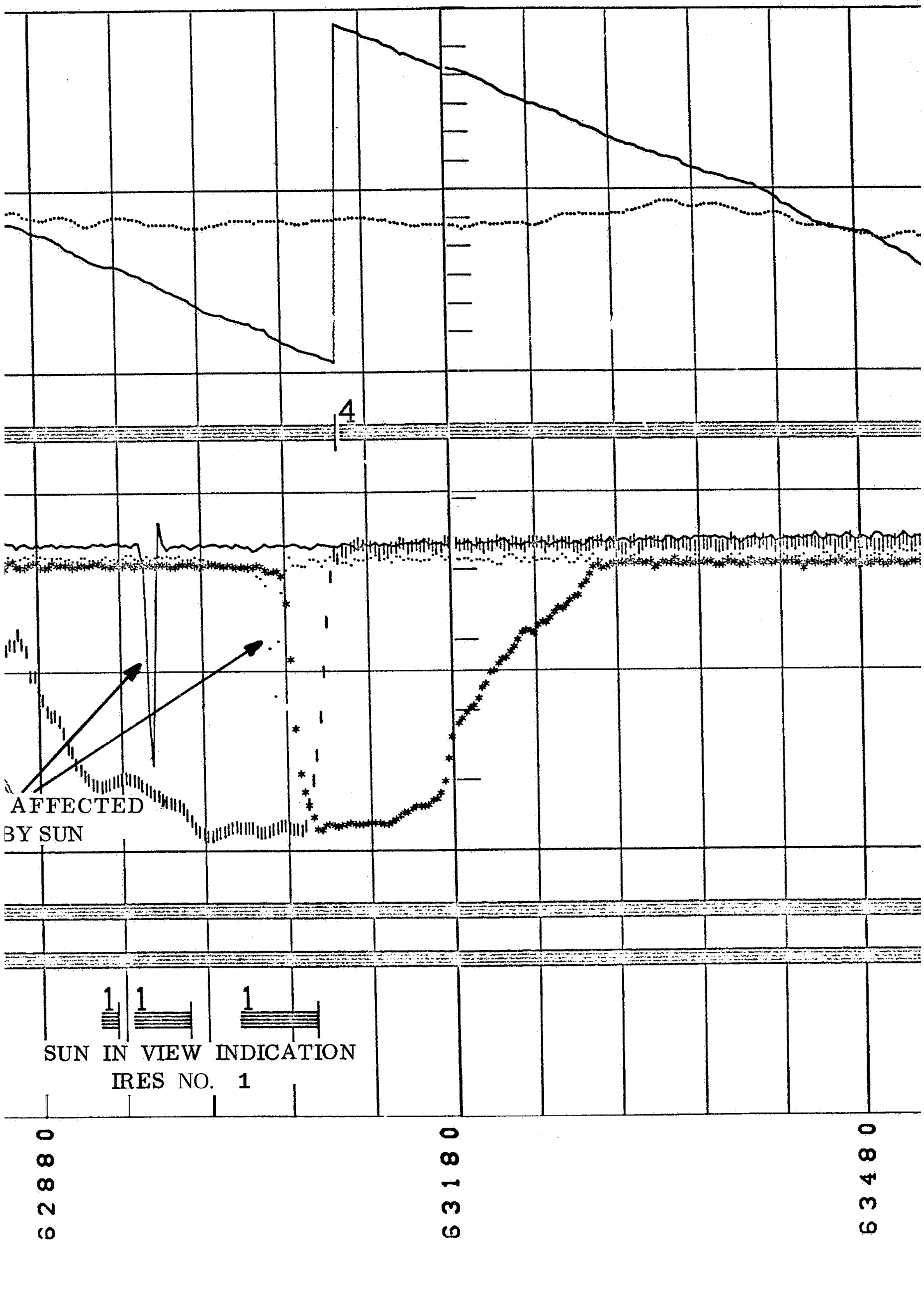


Figure 2-18. Earth Sensor Data (1)- Day 98



SAS
127
100
80
60
40
20
0
-20
-40
-60
-80
-100
-128
SAS (IN USE)
2 1
3
EAS
500
400
300
200
100
0
DAT
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
TIME CSECONDSI
62580



4
AFFECTED
BY SUN
1
1
1
SUN IN VIEW INDICATION
IRES NO. 1
62880
63180
63480

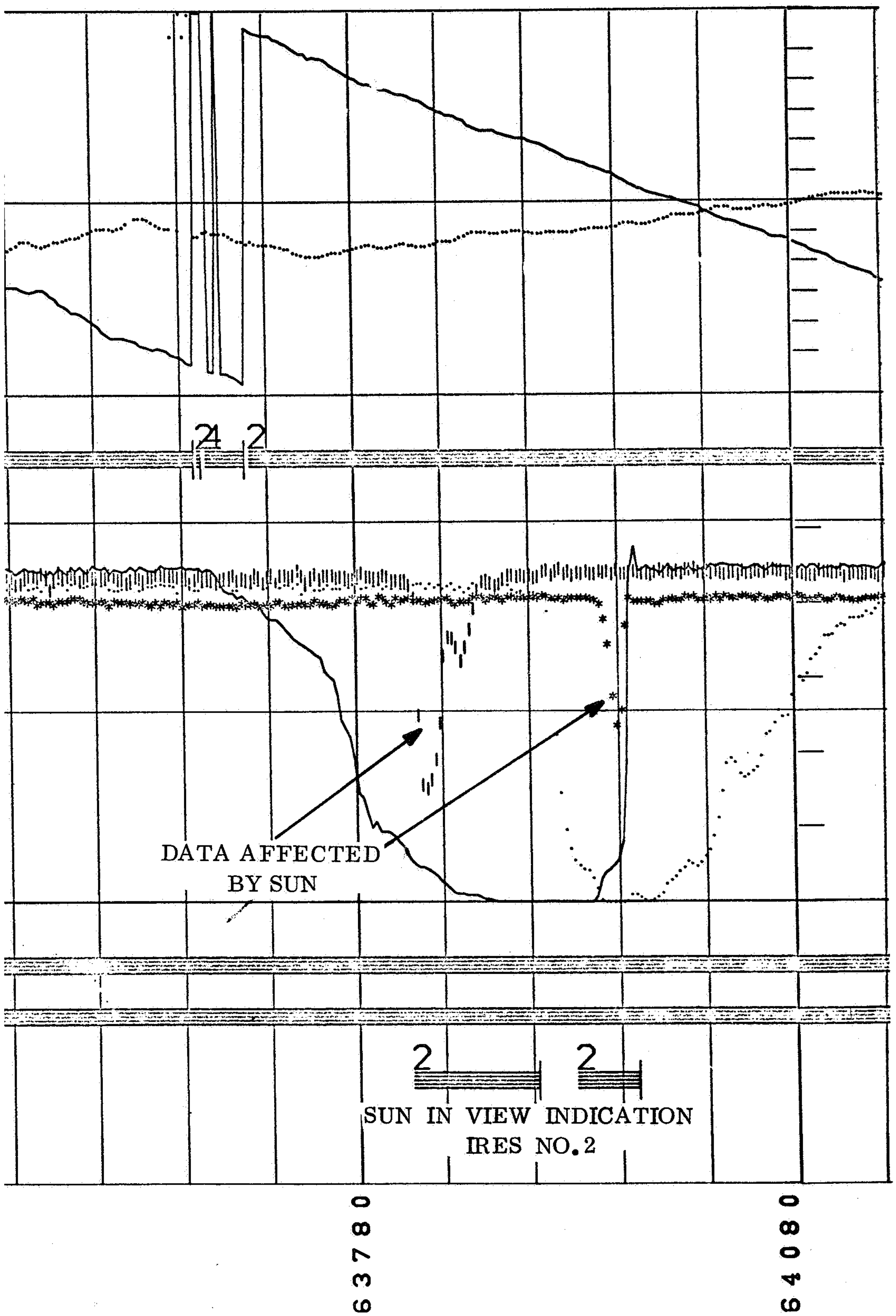


Figure 2–19. Earth Sensor Data (2) - Day 97

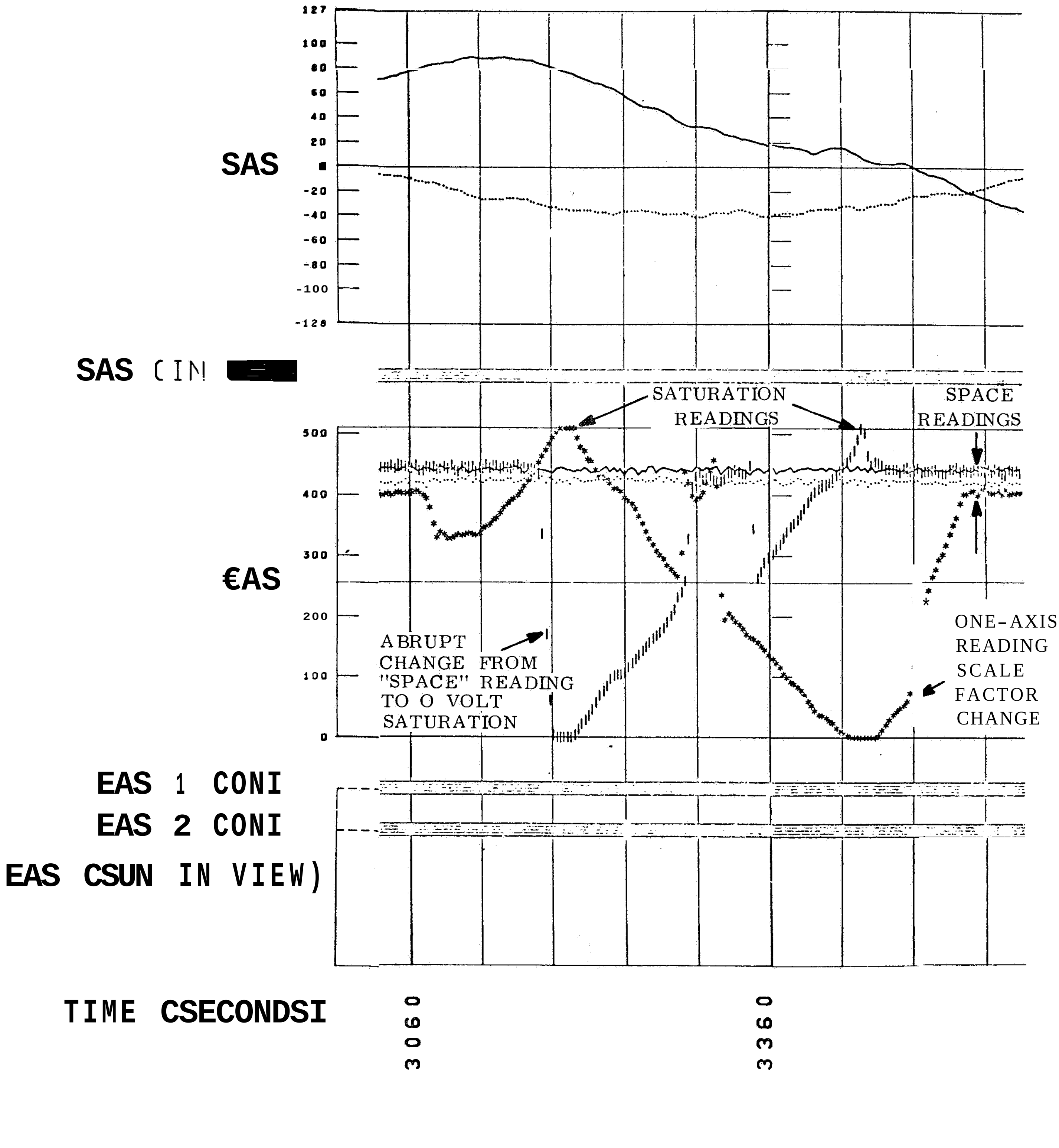
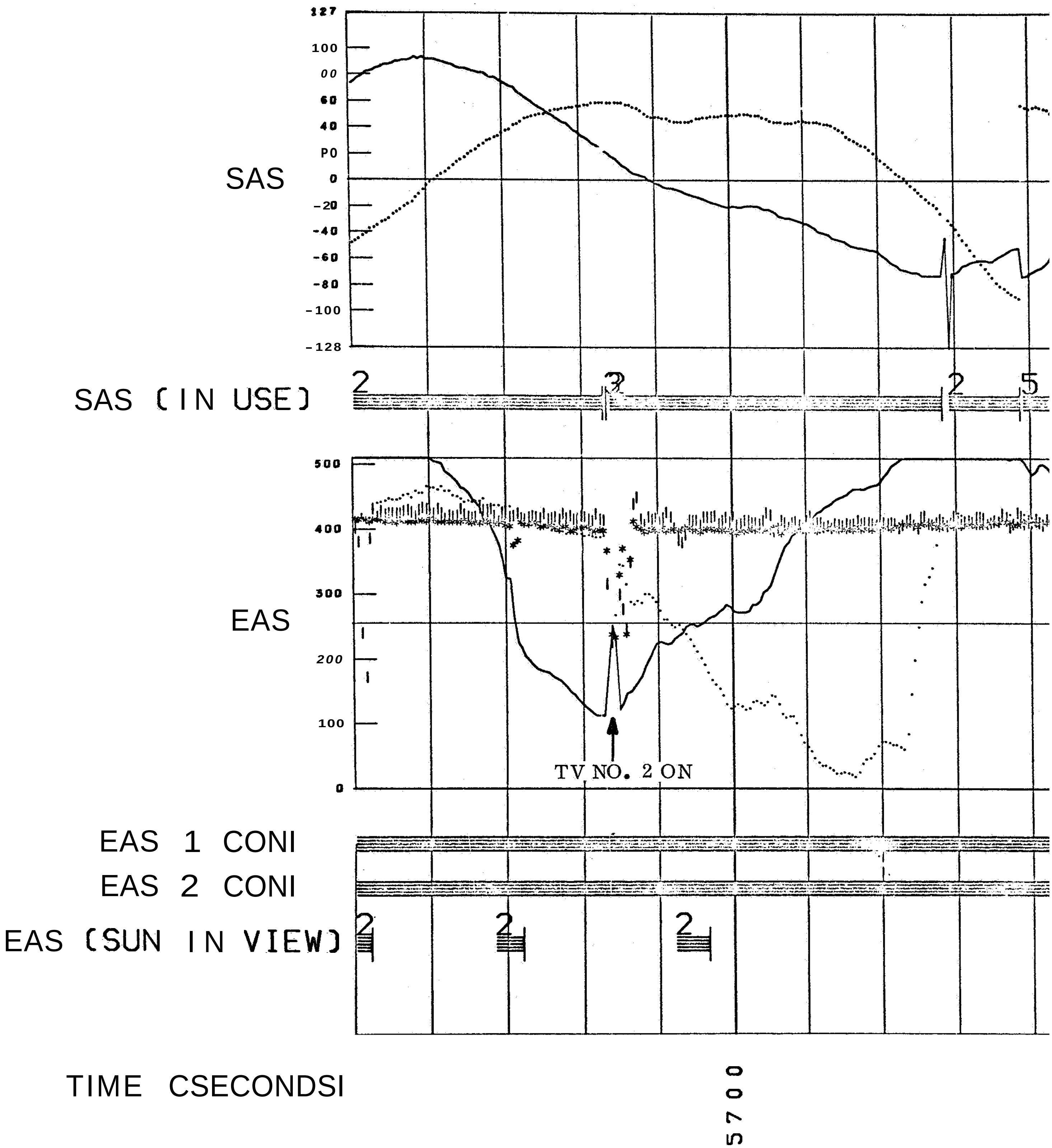
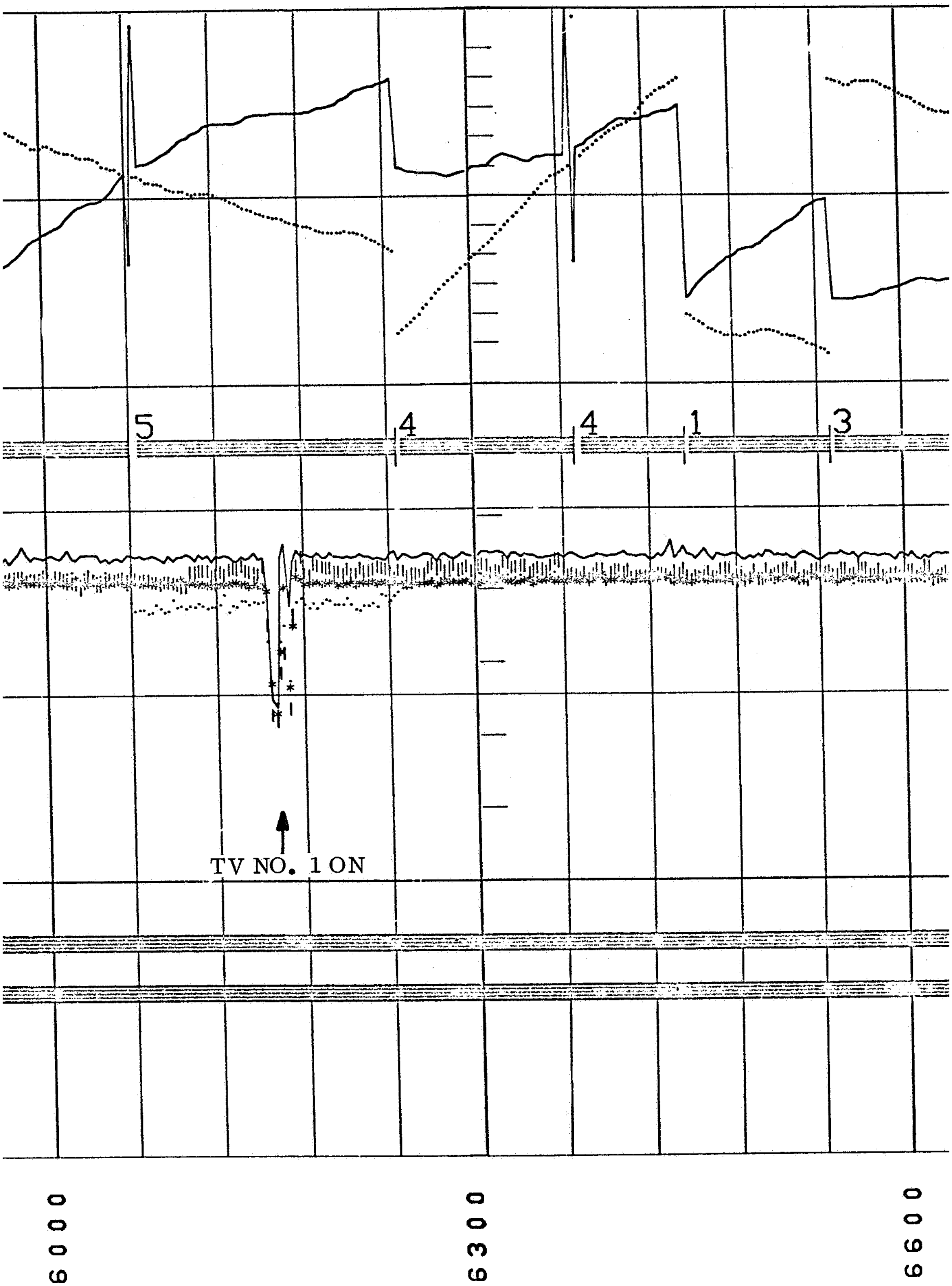


Figure 2-20. Earth Sensor Data (3) - Day 97


127
100
00
60
40
P0
0
-20
-40
-60
-80
-100
-128
SAS
SAS (IN USE)
2
3
2
5
500
400
300
200
100
0
EAS
TV NO. 2 ON
EAS 1 CONI
EAS 2 CONI
EAS (SUN IN VIEW)
2
2
2
TIME CSECONDSI
5700

1-2-67/68



2-2-67 168

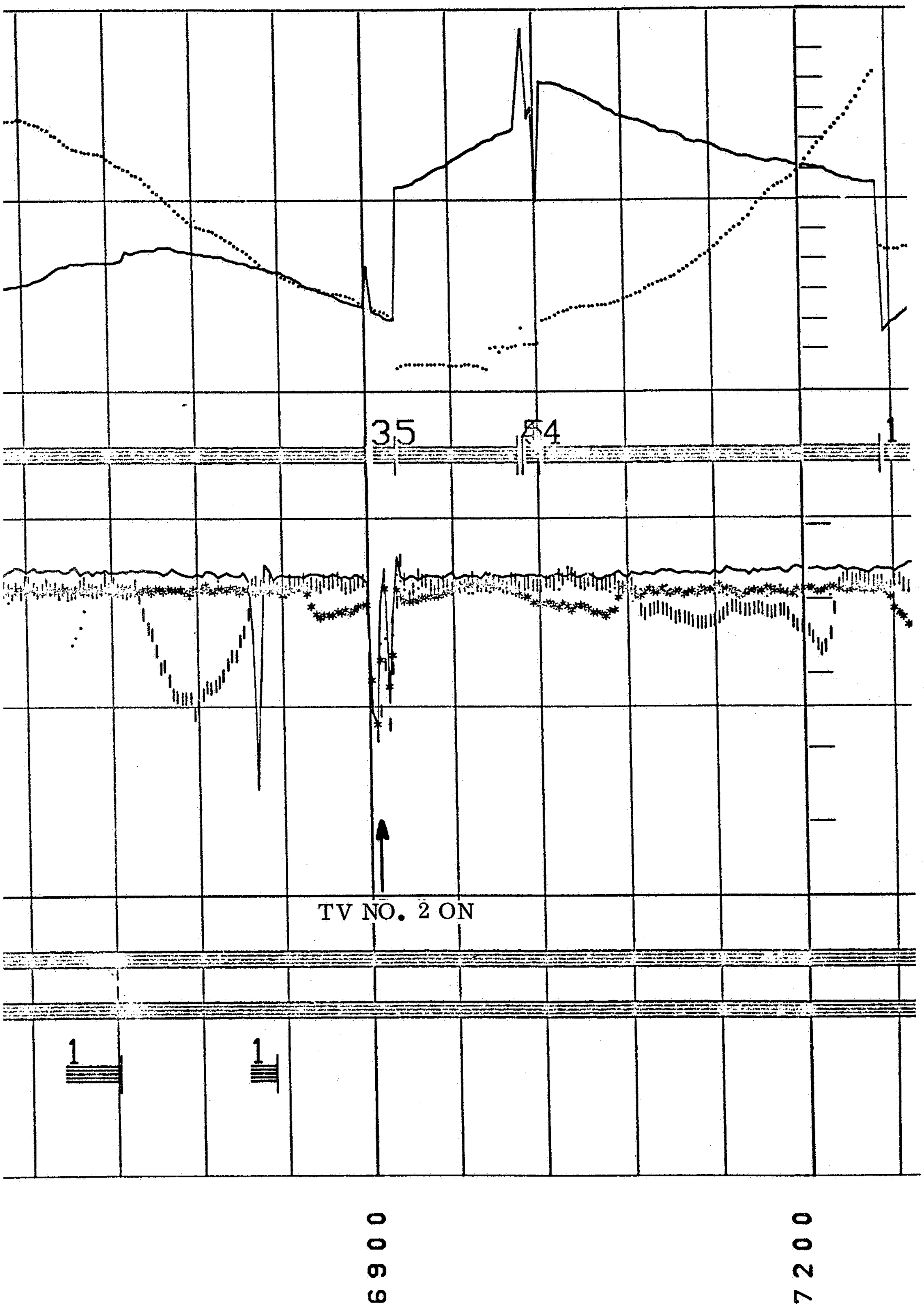


Figure 2-21. Earth **Sensor** Data (2) - Day **98**

[redacted]

3-2-67/68

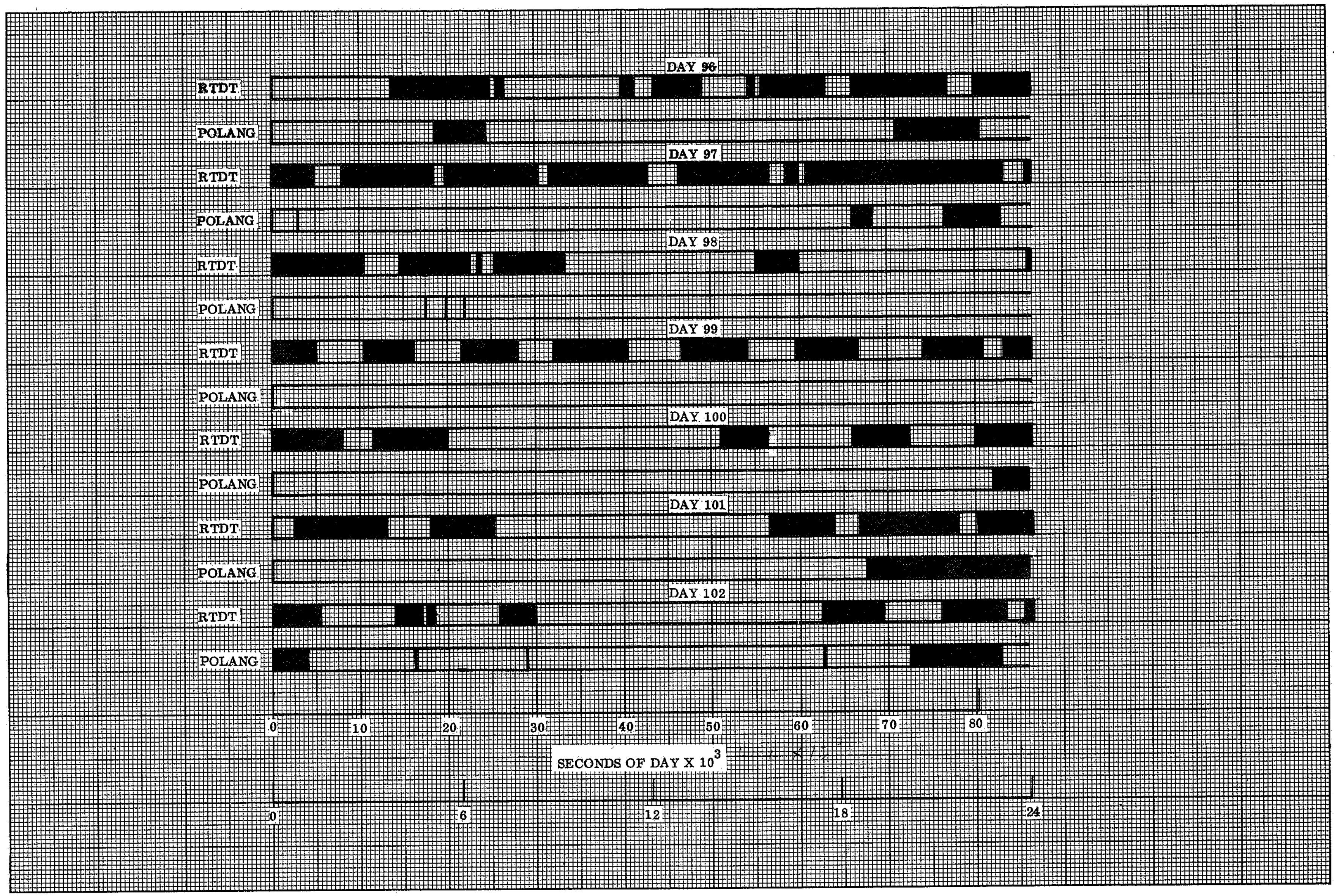


Figure 2-22. Telemetry and Antenna Polarization Measurements (Sheet 1)

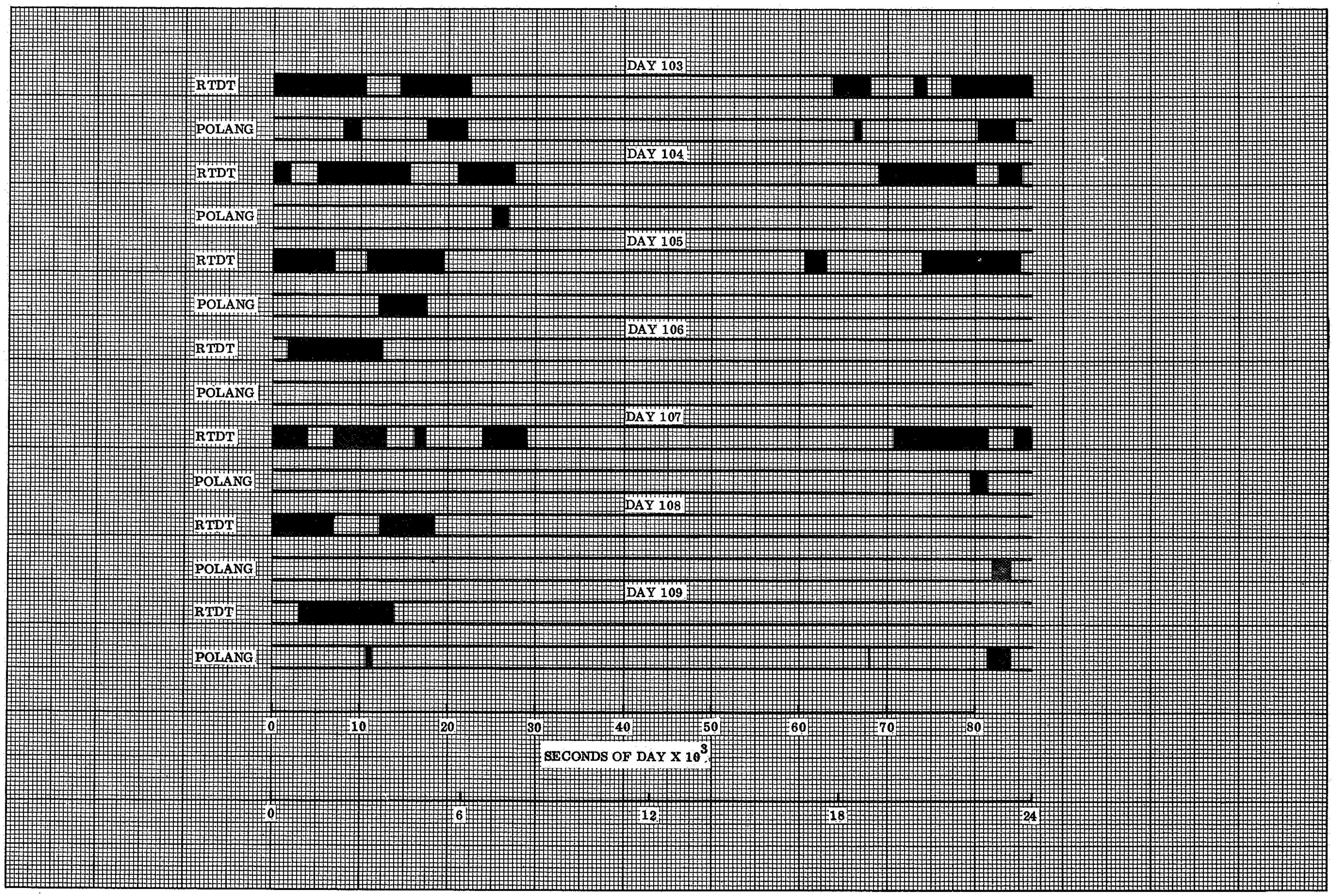


Figure 2-22. Telemetry and Antenna Polarization Measurements (Sheet 2)

Data was also provided by direct teletype transmission in established Gravity Gradient Class II and Special (Quick-Look) message formats. A summary of teletype data messages received is presented in Tables 2-5 and 2-6.

2.2.5.1 Quick-Look System

The unexpected characteristics of the ATS-2 flight test have resulted in virtual disablement of the Quick-Look System. Required existence of valid earth sensor data on both axes has been realized through only two data intervals during initial flight. Valid POLANG data has been confirmed over nine intervals, also. Of these inputs, sun sensor/earth sensor measurements have led to computed attitude in agreement with long-term Attitude Determination Program computations. Three of the nine POLANG data messages resulted in computed attitude, but no coincident results were available from the long-term program for comparison. Attempts at other selected data intervals containing apparently good but unverified data have been unsuccessful.

An inventory of data messages received is presented in Table 2-5; the disposition of each GE Special Data message received is presented in Table 2-6. (Data noted as being unusable has not been included in any attempts at system operation.)

2.2.5.2 Class II Data System

Due to the unexpected characteristics of the ATS-2 flight, continued analysis of Class II data has been suspended in lieu of additional long term data received. Indications from initial data handled demonstrated that this system can serve adequately as a means of periodically surveying spacecraft system health and status. Verification of several command executions was achieved using this system.

An inventory of Class II messages received is presented in Table 2-7.

Table 2-5. **Quick Look** Messages Received

Station	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
Toowoomba	25	12	13	12	0	8	16	3	4	23	5	4	0	11	5	12
Mojave	9	15	0	5	11	7	15	26	0	7	0	3	3	0	0	0
Rosman	23	13	0	0	12	0	1	0	0	0	0	0	0	0	0	0
Totals	57	40	13	17	23	15	32	29	4	30	5	7	3	11	5	12

Station	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111
Toowoomba	26	8	12	0	0	7	17	27	4	25	5	4	0	12	5	11
Mojave	11	10	0	5	12	6	16	4	0	8	0	5	3	0	2	0
Rosman	25	15	0	11	0	0	1	0	0	0	0	0	0	0	0	0
Totals	62	33	12	16	12	13	34	31	4	33	5	9	3	12	7	11

.12	113	116	122	Totals
9	1	3	0	166
0	0	0	0	101
0	0	0	1	50
9	1	3	1	317

L12	113	116	122	Totals
8	0	0	0	171
0	0	0	0	82
0	0	0	0	52
8	0	0	0	305

Table 2-6. Quick Look Data Classification

Day	Message	Message Classification
96	1	Computed; results unconfirmed
	2	Computed; results unconfirmed
	3-6	Unusable data
	7	Computed/confirmed
	8-35	Unusable data
	36	Computed/confirmed
	37-44	Unusable data
	45	Computed; results unconfirmed
	46-47	Unusable data
	48	Unusable data
	49-57	Unusable data
97	1-41	Unusable data
98	1-13	Unusable data
99	1-17	Unusable data
100	1-23	Unusable data
101	1-15	Unusable data
102	1-32	Unusable data
103	1-29	Unusable data
104	1-4	Unusable data
105	1-23	Unusable data
	24	Computed; results unconfirmed
	25-30	Unusuable data
106	1	Unusable data
	2	Computed; results unconfirmed
	3-5	Unusable data
107	1	Unusable data
108	2	Computer; results unconfirmed
	3	Unusable data
109	1-11	Unusable data
110	1-5	Unusable data
111	1-12	Unusable data
112	1-9	Unusable data
113	1	Unusable data
116	1-3	Unusable data

2.3 CRITIQUE ON TV FILM

2.3.1 INTRODUCTION

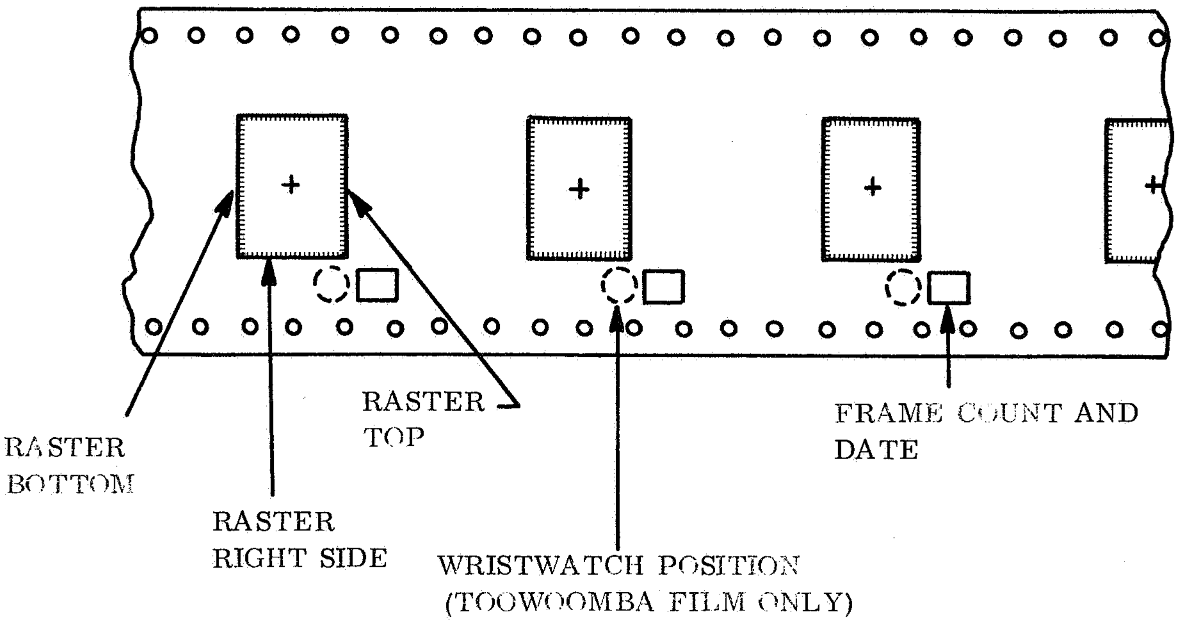
Eleven rolls of 35 mm TV film were received by GE during the period 6 April 1967 through 25 April 1967. In general, all films received were of poor quality and contained an inadequate time code and reticle mark presentation; this prevented implementation of any meaningful data reduction scheme and all films to date are relatively unusable. Quality of data received at the ground stations, based on viewing of recorded video tapes, was good. The problem, therefore, must be inherent in the procedures used to adjust the ground station monitor, photograph the monitor, add time code annotation and/or develop and process the 35 mm film. An inventory or received film data is summarized in the following table. Attempts to digitize data were made on only 3 film rolls.

GE Film No.	From Tracking Station	Orbit No.	System Time From	System Time To	Number of Frames	Boom Data	Earth Data	Date Received	Data Digital
1	Rosman	30	19:30:20	19:36:50	27	No	Yes	4/14/67	No
2	Rosman	30	19:37:05	19:44:35	31	No	Yes	4/14/67	Yes
3	Toowoomba	1	Unknown		30	No	Yes	4/14/67	No
4	Rosman	4	Unknown		21	Yes	No	4/16/67	No
5	Rosman	39	01:06:15	01:15:45	38	Yes	No	4/14/67	No
6	Rosman	39	Unknown		20	Yes	No	4/16/67	No
7	Rosman	45	22:55:55	23:04:25	51	Yes	Yes	4/16/67	Yes
8	Toowoomba	1	02:17:50	06:24:10	156	Yes	Yes	4/20/67	Yes
9	Toowoomba	*	00:42:02	00:48:20	247	No	Yes	4/25/67	No
10	Toowoomba	*	00:49:46	00:00:39	620	Yes	Yes	4/25/67	No
11	Toowoomba	12	01:55:13	05:46:10	867	Yes	Yes	4/25/67	No

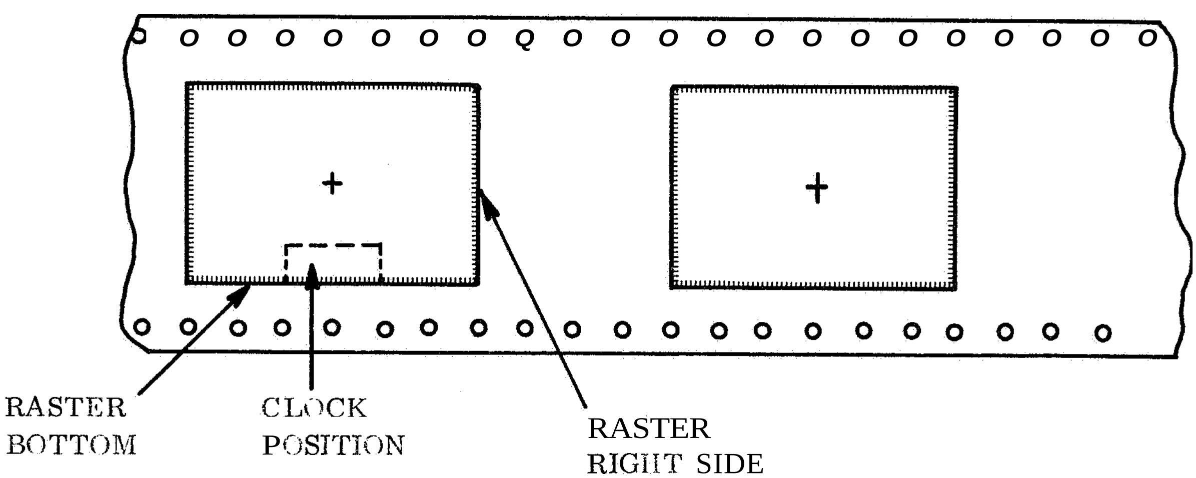
* Probably orbit number 11

2.3.2 GENERAL CRITIQUE

In contrast to the established interface requirements of SVS-7429, "Data Formats Specification," the TV roster on all received film is rotated **90** degrees. The sketch below shows this 90° rotation of the monitor on the film.



This positioning can be accounted for by the Gerber digitizing reader by reversal of scales on the machine. However, full utilization of the film strip is not made and the accuracy of the readings is decreased. Below is a sketch of the film strip required by SVS-7429.



In addition, there appears to be a general lack of cognizance of the fact that the reticles are necessary to the evaluation of the TV pictures. Only on the last films received (No. 8 through 11) have these been sufficient reticles around the pictures; these have been of poor quality. On all other films, the TV monitor controls have apparently been set such that the reticles are visible only when the earth forms a background for the reticles. In all picture frames digitized, locations of reticle positions had to be estimated in at least one area of each frame. This problem, plus the reduction of frame size to 25 percent of that achievable on the film, has an adverse effect on potential accuracy of the TV data system. The lack of adequate time code annotation is even more significant. Without an accurate time code, the pictures are useless even if of the highest quality.

Two of the first four films received were not annotated in time. Other films were supplied with times that were only approximate. The Toowoomba station data as shown in the sketch above was supplied with a wristwatch within the filmed area. However, hard copy annotations of frames and times were supplied which did not agree with the photographed watch. In all instances in the digitzing, the filmed watch was used as a time reference. Toowoomba also generated a film wherein only half the watch is visible in the frames and frame numbers are not shown; this film could not be digitized. In one of the last films received from Toowoomba, the orbit pass during which pictures were taken was uncertain even though clock time was presented.

Following is a film-by-film qualitiative description of each film **roll** received.

2.3.2.1 Film No. 1

a. General Picture Quality - Poor; very dark picture of earch with little or no resolution; one boom shows on some pictures; no boom tips visible.

b. Quality of Reticle - Very poor; is distinguishable only where earth serves as background; no center crossmark visible.

c. Time Code Annotation - Time code received on accompanying hard copy.

2.3.2.2 Film No. 2

a. General Picture Quality - Same as 2.3.2.1 a above

b. Quality of Reticle - Same as 2.3.2. lb. above; crossmark shows when earth acts as background.

c. Time Code Annotation - Same as 2.3.2. 1c above.

2.3.2.3 Film No. 3

a. General Picture Quality - **Fair;** dark pictures but better than 2.3.2. la and 2.3.2.2a above; both booms showing but no boom tips visible; this data taken from video tape.

b. Quality of Reticle - Some pictures are fair, some are poor; apparently experimentation in camera adjustment and/or monitor adjustment was being performed. Poor ones are commensurate with 2.3.2. 1b above.

c. Time Code Annotation - None; data was taken from video tape. Hard copy states station and pass with pictures taken just after boom deployment.

2.3.2.4 Film No. 4

a. General Picture Quality - Fair; skyward-viewing pictures of boom tips only; tips are easily discernible; apparently some adjustments were being made during picture taking because of variable contrast.

b. Quality of Reticle - **Fair** to good on most pictures; poorer pictures conform to 2.3.2. l b above.

c. Time Code Annotation - None; data taken from video tape.

2.3.2.5 Film No. 5

a. General Picture Quality - Poor; very dark pictures of sky and boom tips but tips are discernible.

b. Quality of Reticle - No reticle shows on film.

c. Time Code Annotation - Hard copy gives start time and intervals between shots.

2.3.2.6 Film No. 6

a. General Picture Quality - Poor to excellent; good to excellent pictures show good boom data; variations in pictures shows some adjustment to system was being performed during shots.

b. Quality of Reticle - Good to excellent same as for a above.

c. Time Code Annotation - None; data taken from video tape.

2.3.2.7 Film No. 7

a. General Picture Quality - Fair to excellent; much better earth resolution available than earlier film numbers; boom tip data available.

b. Quality of Reticle - Poor to fair; earth background required to obtain good reticle resolution; where reticle is invisible, it was estimated by drawing it in with pen on digital reader display.

c. Time Code Annotation - Poor; supplied as approximate start time and internal on hard copy; reference was made to command list for better annotation of start time of camera.

2.3.2.8 Film No. 8

a. General Picture Quality - Most pictures are good to excellent; good contrast on earth; booms and tips are visible; this is first reel received with clock within film.

b. Quality of Reticle - Poor to fair; some areas on films had to be estimated by drawing in reticle marks .

c. Time Code Annotation - Good; performed with photographed clock with 18 second correction as per instructions on supplied hard copy. However, correlation with range time is questionable.

2.3.2.9 Film No. 9

a. General Picture Quality - Poor; essentially the same as 2.3.2. 1a; no boom data; very long film so earth movement into picture is quite discernible.

b. Quality of Reticle - Poor as in 2.3.2. 1b above except that center cross is more discernible.

c. Time Code Annotation - Good because clock provided within film; however, hard copy notes doubt of station pass number.

2.3.2.10 Film No. 10

a. General Picture Quality - Fair; first film with full view of earth within pictures; pictures are too dark for good ground resolution; some boom data available.

b. Quality of Reticle - Poor to nonexistent; reticle only shows with earth background; center cross is visible.

c. Time Code Annotation - No frame numbers and only half of the photographed clock are visible evidently caused by camera location; hard copy rotates frame number and time but no frame numbers available.

2.3.2.11 Film No. 11

a. General Picture Quality - Poor to good depending on station pass; majority with earth in view are poor quality too dark but they show significant boom dynamics; pictures with booms only are fair but show little boom motion

b. Quality of Reticle - Majority are poor as described in 2.3.2.1b; TV data with booms only are good.

c. Time Code Annotation - Good; clock shown in film. Correlation with range time, however, is questionable.

2.3.3 CORRELATION WITH SPACECRAFT ATTITUDE DATA

To date, no correlation between TV data and spacecraft attitude data has been obtained. One method utilized was to compute the known included angle between the sun vector and earth vector based on known orbital position at the precise time of a TV picture. Sun sensor data and reduced TV data were then utilized to compute the same angle. No correlation was obtained for any of the three TV film reduced. It should be noted, however, that this technique is quite sensitive to errors in time and time code annotation on all film received is, at best, questionable.

2.3.4 CONCLUSIONS

The present system of obtaining TV data can be made to produce meaningful results only if problems associated with film quality, raster orientation on the film, reticle mark presentations, and time code annotation can be completely resolved; SVS-7429 requirements should be used as a baseline for necessary improvements.

2.4 BOOM DYNAMICS INVESTIGATIONS

The flight of ATS-2 in a nominal orbit would be expected to produce almost negligible dynamic motion of the gravity gradient booms (reference PIR 4T45-23). The orbit achieved, as would be expected, produced noticeable flexible motion of the gravity gradient booms. Direct excitation of both the rigid body and flexible modes through the orbital acceleration will occur. This is shown by examination of the terms in R and $\ddot{\gamma}$ of Equation **23** of PIR 4145d-343 Rev. **A.** ($\ddot{R}$ and $\ddot{\gamma}$ are the acceleration in the distance from the center of the earth and the orbit angle, respectively, and are zero in a circular orbit.)

In modal coordinates this term becomes

$$\phi^T M \begin{bmatrix} L_5 & 0 \\ 0 & J_5 \end{bmatrix} \begin{bmatrix} \ddot{R} \\ \ddot{\gamma} \end{bmatrix}$$

Performing the indicated multiplications this term reduces to

$$\phi^T M \begin{bmatrix} L_5 & 0 \\ 0 & J_5 \end{bmatrix} \begin{bmatrix} \ddot{R} \\ \ddot{\gamma} \end{bmatrix} = A\,(\cos\theta_R \cos\theta_P)\,\ddot{R} + B\,(\sin\theta_Y \sin\theta_R \cos\theta_P$$

$$- \cos\theta_Y \sin\theta_P)\,\ddot{R}$$

$$+ C\,(\cos\theta_Y \sin e_R \cos\theta_P + \sin\theta_Y \sin\theta_P)\,R$$

$$+ D\,(\sin\theta_R)\,\ddot{\gamma} + E\,(\sin\theta_Y \cos\theta_R)\,\ddot{\gamma}$$

$$+ F\,(\cos\theta_Y \cos\theta_R)\,\ddot{\gamma}$$

where **A**, B. *C*, D, E and F are vectors of the same order as the number of modes considered. For the 42-degree of freedom system previously discussed in PIR 4145-223 Rev. **A**:

$$\mathbf{A} = \phi^T M \left| a\ a\ a\ a\ a\ a\ a \right|^T$$

$$B = \phi^T M \left[b\ b\ b\ b\ b\ b\ b \right]^T$$

$$\phi^T M \qquad C = \phi^T M \left[c\ c\ c\ c\ c\ c\ c \right]^T$$

$$D = \phi^T M \left| d\ d\ d\ d\ d\ d\ d \right|^T$$

$$E = \phi^T M \left| e\ e\ e\ e\ e\ e\ e \right|^T$$

$$F = \phi^T M \left| f\ f\ f\ f\ f\ f\ f \right|^T$$

where

$$a = \left| 100000 \right|$$

$$b = \left| 010000 \right|$$

$$c = \left| 001000 \right|$$

$$d = \left| 000100 \right|$$

$$e = \left| 000010 \right|$$

$$\mathbf{f} = \left| 000001 \right|$$

The six coefficients A through F are shown in Table 2-8 for the first 30 modes of the same representation discussed in PIR 4145-223 Rev A. Also shown are the frequencies and periods (in seconds) of these modes. The first six modes are the rigid body modes. They are X, Y and Z translation and θ_X, θ_Y and θ_Z rotation, respectively; all modes are normalized to unit generalized mass.

It can be seen that the R term (seen in coefficients A, B, and C) excites only rigid body motion but the $\ddot{\gamma}$ term (seen in coefficients D, E, and F) drives several of the flexible modes directly. An interesting correlation is seen here in that the modes which are excited directly by $\ddot{\gamma}$ are those modes which exhibit center body rotation; i. e. , the 0.00483, 0.00832, 0.01423, 0.02554, 0.02435, 0.0420, 0.04411, 0.0484, 0.3261 and 0.3271 cps modes (reference PIR 4145-223 Rev A). The periods of these modes are 207, 120, 70, 39, 34, 24, 23, 21, 3, and 3 seconds, respectively. Center body oscillations representative of most of these modes have been observed in the flight data.

Further examination of the terms

$$M \begin{bmatrix} L_2 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} X \\ \alpha_X \end{bmatrix} + M \begin{bmatrix} L_1 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{X} \\ \dot{\alpha}_X \end{bmatrix}$$

(from Equation 23 of PIR 4145d-343 Rev A), shows that when transformed to modal *eo*-ordinates, i. e. ;

$$\phi^T M \begin{bmatrix} L_2 & 0 \\ 0 & 0 \end{bmatrix} \phi\, \xi + \phi^T M \begin{bmatrix} L_1 & 0 \\ 0 & 0 \end{bmatrix} \phi\, \dot{\xi}$$

the nature of L_2 and L_1 provides coupling between the modes so that each mode present acts to force other modes. This transfer of motion from mode to mode is dependent on the magnitude of the body rates $\dot{\theta}_P$, $\dot{\theta}_R$, $\dot{\theta}_Y$ (L_2 and L_1 are functions of these rates and the body orientation) so that the degrees of modal coupling will increase with increasing body rates. More detailed examination of the effects of orbit eccentricity is in progress and will be documented in a forthcoming PIR.

Table 2-8. Coefficients A Through F

Mode No.	Frequency cps	Period	A	B	C	D	E	F
1	0	-	1					
2	0	-		1				
3	0	-			1			
4	0	-				4.0		
5	0	-					0.5	0
6	0	-						-.05
7	.002214	453						
8	.002214	453						
9	.002218	451						
10	.002233	449						
11	.002238	447						
12	.00483	207				−10.6		
13	,00832	120					10.1	6.2
14	.01423	20					12.1	16.9
15	.01680	59						
16	.01680	59						
17	.02554	39					8.7	-5.7
18	.02935	34				−10.2		
19	.03331	30						
20	.03332	30						
21	.03332	30						
22	.03334	30						
23	.03336	30						
24	,04202	24				−22.8		
25	.04411	23					18.7	18.4
26	,04542	21					20.2	−4.0
27	,3239	3						
28	.3240	3						
29	.3261	3					3.7	−2. 8
30	.3271	3				4.6		

SECTION 3

BOOM SUBSYSTEMS

3.1 KEY EVENTS

1 February 1967	S/N 103 (F–1–Bu) Primary Boom returned to deHavilland. S/N 12 (P–2B) Primary Boom received from HAC.
17 February 1967	S/N 10 (P–2) Damper Boom received from HAC.
21 February 1967	S/N 10 (P–2) Damper Boom qualification testing completed at GE.
28 February 1967	S/N 100 (P–1) Primary Boom received from deHavilland.
8 March 1967	S/N 12 (P–2B) Primary Boom qualification testing completed at GE.
9 March 1967	S/N 12 (P–2B) Primary Boom shipped to NASA/GSFC.
13 March 1967	S/N 10 (P–2) Damper Boom shipped to NASA/GSFC.
20 March 1967	S/N 103 (F–1–Bu) Primary Boom received from deHavilland.
23 March 1967	S/N 102 (F–1) Primary Boom final functional at Cape Kennedy. S/N 101 (F–1) Primary Boom final functional at Cape Kennedy.
24 March 1967	S/N 12 (P–2B) Primary Boom received from NASA/GSFC. S/N 100 (P–1) Primary Boom requalification program completed at GE. S/N 11 (P–2A) Primary Boom received from NASA/GSFC.
29 March 1967	S/N 103 (F–1–Bu) Primary Boom Acceptance Test Procedure completed at GE.

31 March 1967	S/N 11 (P–2A) Primary Boom qualification testing completed at GE.
6 April 1967	S/N 101 (F–1B) Primary Boom successfully deployed in space.
	S/N 102 (F–1A) Primary Boom successfully deployed in space.
	S/N 100 (F–1) Damper Boom successfully deployed in space.

3.2 UNIT DESIGNATION

The serial numbers and the application of primary and damper boom units are summarized in Table 3–1.

Table 3–1. Boom System Identification

Designation		Serial No,	Use
Engineering Units			
T-1A	Primary Boom	S/N 2	Development Program
T-1B	Primary Boom	S/N 3	" "
T-1	Damper Boom	S/N 2	" "
Prototype Units			
P-1	Primary Boom	S/N 100	Component Qualification
P-2A	Primary Boom	S/N 11	System Qualification
P-2B	Primary Boom	S/N 12	System Qualification
P-1	Damper Boom	S/N 11	Component Qualification
P-2	Damper Boom	S/N 10	System Qualification
Flight Units			
F-1A	Primary Boom	S/N 102	Flight Unit, ATS–A
F-1B	Primary Boom	S/N 101	Flight Unit, ATS–A
F-1 (BU)	Primary Boom	S/N 103	Flight Unit, ATS–A
F–2A	Primary Boom	S/N 104	Flight Unit, ATS–D/E
F–2B	Primary Boom	S/N 105	Flight Unit, ATS–D/E
F-3A	Primary Boom	S/N 10	Flight Unit, ATS–D/E
F–3B	Primary Boom	S/N 103	Flight Unit, ATS–D/E
F-1	Damper Boom	S/N 100	Flight Unit, ATS–A
F-2	Damper Boom	S/N 101	Flight Unit, ATS–D/E
F–3	Damper Boom	S/N 102	Flight Unit, ATS–D/E

3.3 PRIMARY BOOMS

3.3.1 ENGINEERING UNITS

3.3.1.1 Engineering Unit T-1B (S/N 3)

Primary Boom S/N 3 underwent retrofit to the ATS-D/E configuration tip masses. During the first lateral axis vibration, both tip masses came uncaged at 20 cps. Subsequent inspection of the unit revealed that both latching springs for one tip mass were completely severed at the bend radii and one latching spring for the other tip mass was badly cracked at the same bend radius. In conjunction with the heavier tip masses (8.0 pounds as compared to 2.5 pounds) of the ATS-D/E configurations, a spring plate reinforcement was incorporated into the S/N 3 unit.

The basis for incorporation of this reinforcement was obtained from a structural analysis conducted by GE on the adequacy of the present spring plate configuration for the ATS-D/E tip mass requirements. A review of the vibration records obtained during T-1A engineering testing indicated that the maximum response of the ATS-A tip mass was 50 g's along the critical axis. There was no guarantee that the same response would be obtained when testing the ATS-D/E configuration, but a deviation of at least 23 percent was expected based on this assumption. The results of a conservative analysis indicated that the current plate would have excessively high deflections in the area where the attachment of the 0.005-inch retaining spring is made. These deflections would cause an indeterminate nonuniform stress to be introduced which could be high enough to'precipitate failure at the 0.03-inch bend radius of the spring. If a reasonably stiff spring plate was provided, the stresses calculated for the spring were 66,500 psi tensile and 22,000 psi bending which were acceptable for the material being used (410 SS).

Inspection of spring plates on hand at both deHavilland and General Electric subsequent to the S/N 3 vibration uncaging failure, has revealed that most latching springs were attached to the plates with improper mating of the spring and plate radii. To ensure that these radii are properly fitted, the spring installation procedures at deHavilland are being revised to reflect the critical nature of this installation. All spring plate assemblies to be utilized with ATS-D/E tip masses will conform to the new spring installation procedure. These latching spring procedures ensure that the bent radii are properly mated during installation.

All testing relative to the ATS-D/E tip masses has been discontinued on the S/N 3 Primary Boom, and the unit is retained by General Electric awaiting disposition from NASA/GSFC.

3.3.1.2 Engineering Unit T-1A (S/N2)

All planned tests involving the S/N2 Primary Boom have been completed, and the unit is retained by deHavilland awaiting disposition from NASA/GSFC.

3.3.2 PROTOTYPE UNITS

3.3.2.1 Prototype Unit P-1 (S/N100)

Originally it was planned to qualify the S/N 100 primary booms with the heavier tip masses of the ATS-D/E attached, then to qualify the unit again with the lighter ATS-A tip masses. At the completion of the original planned environmental portion of the component qualification program involving S/N 100 Primary Boom, two failures were evident: (1) the sealed enclosure that is maintained at a pressure of 7.5 psi was found to be leaking; and (2) the boom deployment motor stalled during retraction on the test track. The final failure analysis at deHavilland corroborated the preliminary results reported in the Tenth Quarterly Report (20 February 1967) i.e., that the enclosure leak was at the hermetic connector and the retraction failure was the result of excessive loading during testing. Upon completion of the failure analysis, the S/N100 Primary Boom was fully inspected, rebuilt to the ATS-D/E tip masses and returned to General Electric for resubmittal to the Qualification Test Program. During initial functional tests at GE, difficulty was encountered in uncaging the ATS-D/E tip masses (see Failure Analysis Report 295-E-45). In order to qualify the S/N 100 to the ATS-A configuration in advance of the first flight. the S/N100 Primary Boom was refitted with the ATS-A tip masses and resubmitted to the Qualification Test Program. The results of the entire ATS-A qualification program on the S/N100 Primary Boom are presented in report No. 4315-QC-022. All planned testing relative to the ATS-A configuration has been completed, however, resubmittal to qualification testing will be required for the heavier ATS-D/E tip masses. The ATS-D/E uncaging anomaly experienced on S/N 100 Primary Boom (ballooning or incipient backwinding between the storage drum and the guidance shroud) did not occur during ATS-D/E, S/N3 uncaging tests prior to its vibration failure. This apparent inconsistency in test results between units is believed to be caused by: (1) comparative inefficiency of S/N3 extension drive train due to its excessive vibration history: (2) increased efficiency of S/N100 extension drive train due to improved assembly techniques incorporated as a result of the experienced retraction anomalies and improvement of the extension spiroid set lubrication (Aeroshell 7A now used in place of G300/ MoS_2). Even with these apparent differences in the operational capabilities of the two components, uncaging of the ATS-D/E tip massess will be marginal at best. and design changes will be required prior to submittal of S/N100 Primary Boom to the ATS-D/E Qualification Program.

3.3.2.2 Prototype Units P-2A (S/N11) and P-2B (S/N12)

The P-2A and P-2B Primary Boom units were designated as the system qualification units and they were utilized at HAC and NASA/GSFC for evaluation of the ATS spacecraft. They have been subjected to functional, vibration, thermal-vacuum and acceleration tests at HAC while mounted in the spacecraft. These test results were presented in the Tenth Quarterly Report. Since completion of the formal planned System Qualification Program, S/N11 and S/N12 have undergone magnetic dipole and separation shock tests at NASA/GSFC while mounted in the spacecraft. In addition, these components have been functionally tested at GE to determine their capability of surviving the spacecraft qualification environment.

Anomalies in the post-qualification testing on S/N12 as reflected in Failure Analysis Report 292-E-43 were not considered as qualification failures. The anomalies encountered were backwinding during uncaging and a loose roll pin from the pyrotechnic release mechanism. The backwinding during uncaging resulted from excessive boom damage incurred during an inadvertent overextension while mounted on the spacecraft. The loose roll pin occurred from distortion during repeated pyrotechnic releases without retrofit of the release mechanism. Units subsequent to these two prototypes have had distorted parts of the release mechanism replaced after each explosive release.

Similarly, anomalies in the post-qualification testing on S/N11 as reflected in Failure Analysis Report 300-E-50 were not considered as qualification failures. The anomalies encountered were: an electrical isolation short of the erection unit; uncoordinated extension limit switches; and a cracked latching spring, The erection unit electrical isolation short was caused by a scissor limit switch actuator arm bracket contacting the pyromechanism housing. When these brackets were initially installed, the pyromechanism gear train locking mechanism had not been conceived. Subsequent units fitted with the pyromechanisrn have had these brackets modified so that this interference cannot occur. Continual coordination of all limit switches on subsequent units has also been ensured by bonding the limit switches to their mounts after the proper coordination and operation is attained. The cracked latching spring problem will be corrected on the ATS-D/E units when proper fitting of the spring and plate radii is attained.

All planned tests involving the S/N11 and S/N12 Primary Booms have been completed. Both units are retained by GE awaiting disposition from NASA/GSFC.

3.3.3 FLIGHT UNITS

3.3.3.1 Flight Units F-1A (S/N102) and F-1B (S/N101)

The F-1A and F-1B units were installed in the ATS-A spacecraft. All booms from both units were successfully uncaged and deployed to full length and have been subsequently viewed by the TV cameras onboard the spacecraft. Caging difficulties encountered at Cape Kennedy during the final functional tests on the primary booms have highlighted the critical nature of the caging/uncaging sequence required to attain proper deployment. Primary boom tip masses procedures will be amended for the ATS-D/E components to ensure that the optimum scissor angle and proper supply voltage are attained for this critical caging/uncaging sequence.

3.3.3.2 Flight Unit (S/N10)

The S/N10 Primary Boom experienced a retraction failure, as outlined in the Tenth Quarterly Report, due to excessive loading during testing. This unit is now in the process of being rebuilt at deHavilland.

3.3.3.3 Flight Unit (S/N103)

The S/N103 Primary Boom was supplied to GE as an ATS-A backup unit. While it was undergoing leak testing after welding of the enclosure cover, an excessive unidirectional inward leak was discovered. After numerous unsuccessful attempts to stop this leak at GE, the unit was returned to deHavilland for a complete failure analysis and rework. The source of the leak was discovered to be at the enclosure/bellcrank housing interface weld. Improved manufacturing and leak testing techniques initiated on this unit during rework will be utilized on all subsequent units to ensure no recurrence of this failure. After rework of the discrepant weld, the S/N103 Primary Boom was subsequently received at GE as a ATS-A backup unit. The unit successfully completed the required acceptance test.

3.3.3.4 Flight Units F-2A (S/N104) and F-2B (S/N105)

The S/N104 and S/N105 Primary Booms are in the manufacturing cycle at deHavilland. Upon successful completion of acceptance testing. these units will he placed in bonded storage at GE for later delivery.

3.4 DAMPER BOOM

3.4.1 ENGINEERING UNITS

3.4.1.1 Engineering Unit T-1 (S/N2)

Prior to launch of the ATS-A spacecraft, a series of simulated spacecraft damper boom deployment tests was conducted on S/N2 Damper Boom at GE to ensure that the spacecraft opening was sufficient to allow proper damper boom tip mass deployment in orbit. These tests indicated that the spacecraft opening was more than adequate for proper deployment of the ATS-A configuration damper boom, but the more pronounced tip mass rotation inherent in the ATS-D/E configuration damper boom will require an increase in the opening for the ATS-D/E configuration damper booms.

All planned tests involving the S/N 2 Damper Boom have been completed, and the unit is retained by GE awaiting disposition from NASA/GSFC.

3.4.2 PROTOTYPE UNITS

3.4.2.1 Prototype Unit P-2 (S/N 10)

The P-2 Damper Boom was designated as the system qualification unit and was utilized at HAC and NASA/GSFC for evaluation of the ATS spacecraft. The damper boom has been subjected to vibration, thermal-vacuum and acceleration tests at HAC while mounted in the spacecraft. These test results were presented in the Tenth Quarterly Report. Since completion of the formal planned System Qualification Program, S/N10 has undergone magnetic dipole and separation shock tests at GSFC while mounted in the spacecraft. In addition, this component has been functionally tested at GE to determine its capability of surviving the spacecraft qualification environment.

All planned tests involving the S/N10 Damper Boom have been completed and the unit is now being retained at GE awaiting final disposition by NASA/GSFC.

3.4.2.2 Prototype Unit P-1 (S/N11)

All planned tests involving the S/N11 Damper Boom have been completed, and it is retained by GE awaiting disposition from NASA/GSFC.

3.4.3 FLIGHT UNITS

3.4.3.1 Flight Unit F-1 (S/N100)

The S/N100 Damper Boom was installed in the ATS-A spacecraft. Both booms from this unit were successfully deployed to full length.

3.4.3.2 Flight Unit F-3 (S/N102)

The S/N102 Damper Boom has completed the manufacturing cycle at deHavilland and is awaiting the start of acceptance testing. Upon successful completion of the ATP, this unit will be placed in bonded storage at GE for later delivery.

3.4.3.3 Flight Unit F-2 (S/N 101)

The S/N101 Damper Boom experienced premature tip mass release during shipment to Acton Laboratories for acceptance environmental testing. Subsequent testing and inspection at deHavilland revealed no resultant damage and the unit was resubmitted for acceptance environmental testing which was completed. During the post-environmental deployment test at deHavilland, hesitation and cracking anomalies were experienced (see Preliminary Failure Analysis Report 296-E-46). A complete failure analysis is in process at deHavilland but preliminary results indicate that the cracking is due to a more severe overtest than the previous configuration tests, and the hesitation is probably due to improper oscillation damping.

SECTION 4

COMBINATION PASSIVE DAMPER

4.1 HARDWARE STATUS

a. Flights No. 2 and 3. Assembly of both units is complete up to installation of Variable Torque Hysteresis Damper (VTHD).

b. Prototype No. 2. Retest completed, see Section 4.2.1.

4.2 TESTING AND RESULTS

4.2.1 PROTOTYPE NO. 2

After the Prototype No. 2 CPD was returned from HAC following system qualification tests, functional tests were attempted. However, these tests were hampered by an apparently sticky suspension system.

It was suspected that the pyrolytic graphite retaining rings had come unseated. Partial tests were conducted to show that the CPD was magnetically good and free from contamination before it was assembled. A minimum amount of disassembly was done to reseat the rings; the CPD was retested satisfactorily. It should be noted that the retaining rings on all flight CPD's have been secured with epoxy.

4.3 SUMMARY AND CONCLUSION

All tests were passed satisfactorily after the rings were reseated. Differences in test results are attributed to test eqyipment variations and operator judgement. These results are given in Table **4-1.**

Additional observations during disassembly included:

a. Solenoid and lamps functioned properly.

b. Torsional restraint mounting brackets did not fracture even though they were of the old design.

c. Unit was very clean internally in spite of all the handling and testing over the previous 11 months.

Table 4-1. CPD Prototype NO, 2 Test Results Summary

Test	Requirement	Pre-Environment 3/86	Post-Environment 2/67
Visual Inspection	No visible defects	Passed	Passed
Impedance	Tabulated	Passed	Passed
Insulation Resistance	Over 50 megohms	Passed	Passed
Electrical Power	Proper response/display	Passed	Passed
Radial Force Ambient	Over 10 dynes	10.95 dynes/mil	10.54 dynes/mil
Radial Force $\perp$ Ambient	Over 10 dynes	14.85 dynes/mil	13.90 dynes/mil
Torsional Restraint Eddy Current Mode	21.0 to 25.2 dyne cm/deg	21.85 dyne cm/deg	22.4 dyne cm/deg
Soft Stop Torsion ccw Ambient	1000 $\pm$ 10% cm/deg	765 dyne cm/deg	755 dyne cm/deg
Soft Stop Torsion cw Ambient	1000 $\pm$ 10% dyne cm/deg	(1)	686 dyne cm/deg
Eddy Current Damping Ambient	1.34 x 10^4 to 1.82 X 10^4 dyne cm/deg/sec	1.52 x 10^4 @ 0.1°/sec 1.50 x 10^4 @ 0.05°/sec 1.42 x 10^4 @ 0.03°/sec	1.44 x 10^4 @ 0.1°/sec 1.44 X 10^4 @ 0.05°/sec 1.39 X 10^4 @ 0.03°/sec
Torsional Restraint Hysteresis Mode Ambient	21.0 to 25.2 dyne cm/deg	21.8 dyne cm/deg	21.3 dyne cm/deg
Hysteresis Daniping Torque Ambient	147 to 199 dyne cm	177 dyne cm	171 dyne cm
Angle Indicator	See Specification	(2)	(2)

(1) Initial test in this direction invalid due to soft stop being misaligned

(2) 3/66 results were out of specification. However, 2/67 results agree with previous results indicating no change.

4.4 VARYING TORQUE HYSTERESIS DAMPER (VTHD)

NASA/GSFC accepted the proposal submitted by GE on 2 February 1967 to change the hysteresis damping torque of the Passive Hysteresis Damper (PHD) in the Combination Passive Damper for Flights ATS-D and ATS-E from a constant value to a varying function; the value to be dependent on the angular displacement of the damping disc from the null position. The proposal effort covered the resources required to design, develop, fabricate, and test the VTHD.

The development testing of the VTHD has been completed and the drawings and specifications were released. The Engineering Unit (PHD) was reworked to the variable damping torque configuration. It was subjected to functional and vibration testing and suffered no apparent degradation or performance changes because of the vibration environment.

The damping characteristic of the engineering unit is shown in Figure 4-1. A slight adjustment in the magnet spacing would increase the torque beyond ± 10 degrees and allow the torque to be nearer nominal values than on the low side of the tolerance. This adjustment was not made on the engineering unit to accelerate the schedule for the flight units. The engineering report will be issued in May, and it will present a comprehensive report on the development program.

The piece parts'to be used in the flight VTHD's have been manufactured and are being processed at the present time. It is anticipated that the ATS-D VTHD will be completely reworked and tested in early May.

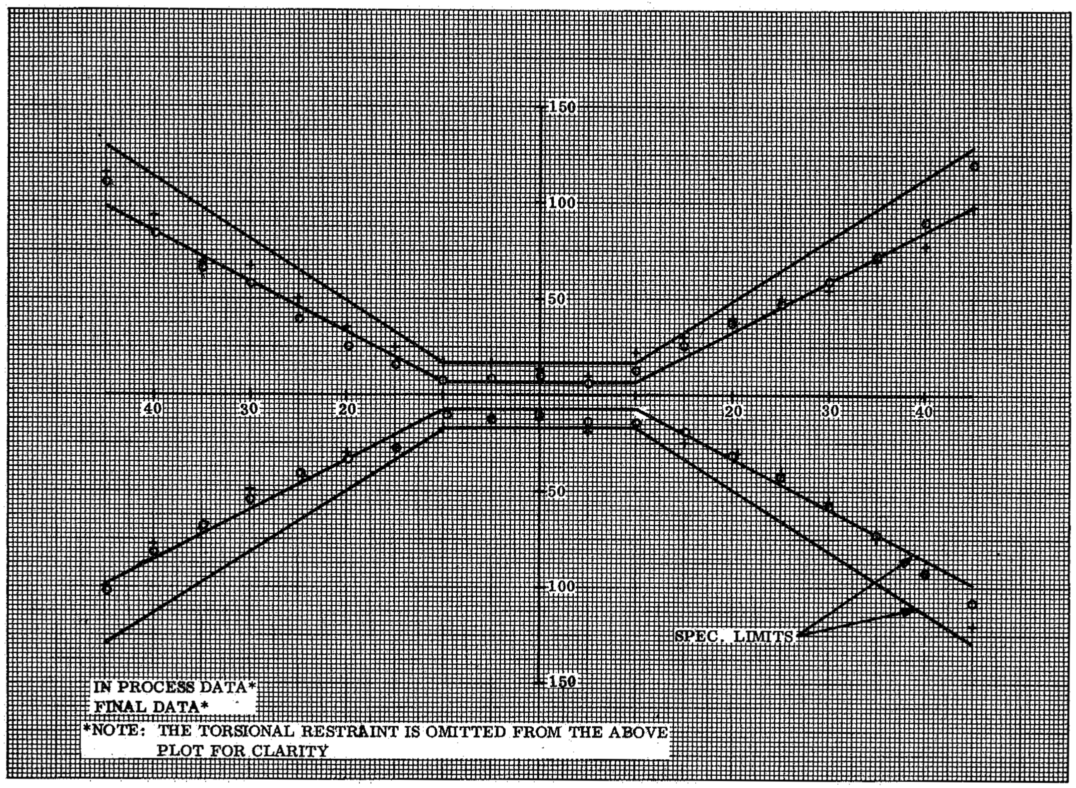


Figure **4-1.** Variable Torque Hysteresis Damper Engineering Unit 1

SECTION 5

ATTITUDE SENSOR SUBSYSTEM

5.1 TV CAMERA SUBSYSTEM

All drawings and specifications were updated to reflect the latest flight configurations (including ATS-D and E) of the TVCS.

The Component Qualification Unit (TVCS No. 5104) was shipped to NASA/GSFC per NASA Direction.

TVCS No. 5108 passed the first storage life test late in March, and was replaced in bonded stock, It will be tested again in May.

A special sun shutter actuation test was performed to determine the lowest regulated bus voltage at which the sun shutter would continue to perform properly. It performed properly as the voltage was dropped to -15 vdc; below 15 vdc it failed to actuate open with no sun, and below 11 vdc it failed to actuate closed with 1.0 sun on the sensor.

Flight TVCS No. 5109 was repaired following the video loss reported last quarter (Page 5-2 of the Tenth Quarterly Progress Report). The two video output transistors failed {collector shorted to base). The camera was returned to the burn-in and acceptance test cycles, and a series of problems was encountered. These problems were as follows:

a. Shutter Failed to Open at Low Temperature: The vendor neglected to remove a current-limiting resistor in the circuit. This resistor was removed to solve the problem noted.

b. Video defocusing: This defocusing was caused by deposition of outgassing materials on the inside of the window. The problem was solved by completely outgassing the unit in a vacuum, cleaning the window, and rerunning the test to verify the absence of additional outgassing.

c. Blanking Loss (Partial) at High Temperature: This was solved by changing the value of a resistor in the blanking circuit.

d. Poor Linearity and Resolution: These were solved by replacing the vidicon spacer ring that positions the vidicon relative to the optics.

e. Vibration Failure of a Capacitor and the Sun Shutter Detent Slug: These were mechanical failures and were corrected by installing the parts using conformal coating and Loc-Tite.

TVCS No. 5109 was re-acceptance tested following the rework to solve the problems listed. The unit passed the test sequence and was placed into bonded stock during April.

5.2 SOLAR ASPECT SENSOR

As stated on Page 5-3 of the Tenth Quarterly Progress Report, the Flight 3 SAS was returned to the vendor (Adcole) for repair of an intermittent connection and to exchange the Electronics Unit case with that from the PO-3 prototype. The rework was satisfactorily performed, and the unit was returned to GE during the week of 20 February. The acceptance tests were completed two weeks later. The sensor has been placed in bonded stock and will be packaged for long-term storage according to GE PIR No. 41M2-ATS-143.

SECTION 6

GROUND TESTING

6.1 ENGINEERING EVALUATION TESTS

6.1.1 PRIMARY BOOMS

Tests involving the primary boom are outlined in Section 3.3.1.

6.1.2 COMBINATION PASSIVE DAMPER

The engineering tests of the varying torque hysteresis damper have been completed (see Section 4.4).

6.2 COMPONENT QUALIFICATION

The qualification program is summarized in Table 6-1.

Table 6-1. Qualification Program Summary

Component	Qualification Status	Remarks
PCU	Test Completed	Test Report No. 4315-QC-003 issued 7/14/66
Damper Boom	Test Completed	Test Report in process
CPD	Test Completed	Test Report issued 1/16/67
SAS	Test Completed	Test Report 4315-QC-007 issued 8/31/66
TV Camera	Test Completed	Test Report No. 4315-QC-021 issued 1/13/67
Primary Booms	Tests in Process	See Section 3 for problem discussion

6.3 SYSTEM QUALIFICATION

NASA directed that acoustic and shock tests be performed on the Y-2 vehicle at Goddard Space Flight Center. GE supplied the P-2B primary boom (S/N12) for this test along with tip targets from Flight 3.

The acoustic and shock tests were completed during the week of 20 March. No problems occurred on the GE components during this test.

6.4 FLIGHT SYSTEM

A short functional test was conducted at HAC on 4 March and all components were operated successfully. The flight spacecraft left HAC on 6 March via trailer for NASA/GSFC. Plans were made to clean and paint some of the GE components on the flight spacecraft while it is at GSFC.

The spacecraft arrived on 9 March. Magnetic dipole measurements were made and compensating magnets were installed in the spacecraft, and all axes were then measured at less than 500 pole-cm. During the time the spacecraft was at Goddard, GE representatives cleaned the gravity gradient sensors. The spacecraft was shipped from NASA/GSFC on 15 March and arrived at Cape Kennedy on 17 March.

Primary boom functional tests were completed successfully. During caging operations conducted the following day, one of the primary boom tapes (Boom A of S/N 102) buckled. It was concluded as a result of troubleshooting that the voltage was too low for the caging operation which caused excessive application of manual pressure. After correcting the tape and input voltage, both booms were successfully caged.

The TV camera, IRES, and SAS were checked out and inert squib firing and damper simulator checks were completed. Eight live squibs were installed on the spacecraft on 27 March and the final GE hangar checkout list was fmished. This checkout included verification of connector mating, removal of the TV lens cover, and removal of the damper safety strap. The spacecraft and adapter were mated to the shroud and the spacecraft and adapter were mated to the Agena on the launch pad on 30 March.

GE participated in launch and orbit support operations for the launch of ATS-2 on 5 April 1967. Failure of the Agena second burn placed the satellite in an eccentric orbit. All GE hardware performed according to plan.

SECTION 7
QUALITY CONTROL

7.1 PRIMARY BOOMS

Systems Qualification Primary Booms S/N 11 and S/N 12 were subjected to a performance test at GE upon completion of systems qualification at HAC. Several difficulties were encountered on each unit. S/N 11 had an anomalous noise in the gear box which eventually disappeared and the extension telemetry limit switch did not actuate a full extension. In addition, a short was caused during boom isolator test by the scissor limit switch actuator arm bracket coming in contact with the pyromechanism housing. Engineering changes pertaining to the limit switch installation and a newly designed part were incorporated into the component qualification and flight units. During initial performance tests on S/N 12, problems were encountered in uncaging and with cracked tape. These problems were attributed to earlier tape creasing difficulties at HAC and the method of recaging the component at HAC prior to shipment to GE. The damaged tapes were removed from the erection unit and a series of successful caging tests were conducted.

Qualification testing of S/N 100 was completed for ATS -A flight. The unit was returned to deHavilland for rework to the ATS-D and E configuration. A series of qualification tests to the S/G configuration will be conducted at GE upon completion of retrofit.

Acceptance testing of S/N 103 as a backup for Flight No. 1 was completed with the exception of final straightness and alignment tests. This unit is now being held pending a decision to retrofit the tip masses to the ATS-D/E configuration.

QC and Manufacturing Engineering made a trip to deHavilland to investigate leak problems on Primary Boom S/N 103.

Vendor Quality Assurance assited deHavilland in the preparation of detailed inspection procedures to be incorporated into primary boom planning. This effort at deHavilland is now completed.

Due to the addition of extra weights to the primary boom tip masses, it was necessary to move the vibration tests from a C125 vibration machine to the C210 vibration machine. All preliminary surveys have been completed and a new test utilizing an averaging technique has been programmed. The component standing instruction will be changed accordingly.

QC Engineering Test Reports 4315-QC-022 and 023 pertaining to the acceptance tests of Flight No. 1 Primary Booms S/N 101 and 102 were issued.

Full time vendor surveillance activity at deHavilland continued during the period.

The following Failure Analysis Reports were issued:

> Supplement No. PA to F. A. R. 269-E-33 on S/N 10; this is a continuing report pending further corrective action.
>
> F. A. R. 295-E-45 pertaining to uncaging problems of S/N 100 when tested with ATS-D/E (8-pound) tip masses; this report is open pending corrective action.
>
> F. A. R. 299-E-49 pertaining to blown fuse in take-up mechanism that caused a backwind on S/N 103; this report is open pending corrective action.
>
> F.A.R. 292-E-43 pertaining to tape damage on S/N 12 at HAC; this report is open pending corrective action.

7.2 DAMPER BOOMS

Systems qualification Damper Boom S/N 10 was received from HAC for a final performance test after being subjected to qualification environments on the Y-2 vehicle. The unit was successfully deployed on the GE test track, Quality Control Engineering Test Report 4315-QC-005-1 pertaining to the additional tests was issued.

The test report on the component qualification Damper Boom S/N 11 was received from deHavilland. This report was rejected for incompleteness after review by GE Design and Quality Control Engineering. The report was submitted a second time, and once again it was found to be unsatisfactory. As a result, it was decided that the report would be prepared by GE.

Flight No. 2 Damper Boom S/N 101 was subjected to vibration and thermal-vacuum tests by deHavilland. The unit failed to fully extend upon completion of the tests. Failure Analysis Report 296-E-46 pertaining to the above failure has been issued. This report is open pending further corrective action and evaluation tests by deHavilland.

Supplement No. 2 to Failure Analysis Report 228-E-17 on Damper Boom S/N 11 was issued. This report is now complete.

7.3 COMBINATION PASSIVE DAMPER

Performance tests on Systems Qualification Unit, Prototype No. 2, were completed during the period. After rework of a loose pyrolytic graphite retaining ring, the unit successfully passed all tests. The solenoid and lamps functioned properly. No degradation had taken place during systems qualification tests. Slight differences in damping and force values were attributed to test equipment and personnel variations. Failure Analysis Report 291-E-42 pertaining to the loose retaining ring was issued. The QC Engineering Test Report pertaining to the above test was also issued.

The acceptance test report for Flight No. 1 Combination Passive Damper was issued by QC Engineering.

Quality Control technicians are assisting in the performance of engineering evaluation tests on the variable torque hysteresis damper.

7.4 TELEVISION CAMERA SYSTEM

Camera System S/N 5108 successfully passed a 60-day shelf life test which was conducted in March. QC Engineering Test Report 4315-QC-025 pertaining to the original acceptance test and QC Engineering Test Report 4315-QC-030 pertaining to the 60-day shelf life test were issued.

Acceptance testing of S/N 5109 was completed during April. During the acceptance test cycle, the unit experienced several difficulties such as shutter failure, defocusing and a capacitor coming loose during vibration. All items were reworked and the unit was accepted.

The following Failure Analysis Reports pertaining to TVCS were issued:

F. A. R. 285-E-39 pertaining to sun shutter problems; this report is now closed.

F. A. R. 288-E-40 pertaining to loss of video signal; this report is now closed.

F. A. R. 290-E-41 and Supplement No. 1, pertaining to defocusing and intermittent shutter; this report is now closed.

F. A. R. 293-E-44 pertaining to shutter failure; this report is open pending corrective action.

F. A. R. 293-E-47 and Supplement No. 1, pertaining to a loose capacitor problem; this report is now closed.

7.5 SOLAR ASPECT SENSOR

A trip was made to Adcole for final inspection of the Flight No. 3 component. The unit was shipped to GE where acceptance tests were satisfactorily completed.

Quality Control Engineering Test Reports 4315-QC-233 and 4315-QC-028 pertaining to the acceptance test of Flights No. 2 and 3 components were issued.

Failure Analysis Report 298-E-48 pertaining to erratic test point readings on Connect J-8, Flight No, 3 SAS was issued. All corrective actions were taken and the report is now closed.

7.6 SYSTEMS TEST

Systems Test personnel participated in the final acceptance of the flight vehicle at Hughes Aircraft Company, the dipole test at Goddard Space Flight Center, and the final prelaunch checkout of the spacecraft at Cape Kennedy.

7.7 GENERAL

The Quarterly Product Assurance Audit Report for the first quarter of 1967 was completed and delivered to the customer.

Component qualification test reports on the SAS, PCU, CPD and TVCS were reviewed and accepted by NASA during this period.

SECTION 8
MATERIALS AND PROCESSES

8.1 BOOM SYSTEM

The solar reflectance values for samples of boom material from S/N 100 were determined in the as-received condition and after qualification vibration and thermal-vacuum testing. The values for both sets of data were within specification values.

Reflectance	
As-Received	Post-Test
0.883	0.882
0.878	0.882
0.889	0.882

It was recommended to Engineering that approval be given to deHavilland's proposed revision of their silver plating specification, DHC-SP-SG. 113. The change would reduce the silver plating thickness from 0.0002 ± 0.0001 inch to 0.00006 ± 0.00003 inch. Samples of material with the lower thickness silver were checked and determined to have reflectance values within specification.

The specification "Primary Boom Assembly Welding, Repair of", No. 171A4529, was prepared and issued.

Materials acceptance and process control tests were run on 23 incoming materials and parts.

SECTION 9

MANUFACTURING

Technical support was provided by the Manufacturing operation during assembly and test of the ATS gravity gradient stabilization system. The manufacturing status of the systems is summarized as follows:

a. Prototype 1

Fabrication of all units comprising the Prototype 1 system is completed. The primary boom unit was returned to deHavilland for conversion to the ATS-D/E configuration.

b. Prototype 2

Fabrication of all components is complete.

c. Flight Units

1. Flight 1 - Flight 1 hardware was launched onboard the ATS-A on 5 April 1967.

2. Flight 2 - SAS, TV Camera, and PCU are complete. CPD is assembled to the point of installation of the hysteresis damper. Definition of assembly of variable torque hysteresis damper was received on 1 May. Damper Boom (S/N 102) is in test at deHavilland; anticipated delivery to GE during May. Primary boom system is in process of assembly and test at deHavilland; anticipated delivery to GE for S/N 103 is in May and S/N 10 is in June.

3. Flight 3 - SAS, TV Camera, and PCU are complete. CPD held at final assembly waiting modification of hysteresis damper to variable torque. Definition was received on 1 May. Damper Boom (S/N101) is in process of assembly and test at deHavilland; anticipated delivery to GE is in June. Primary boom system is in process of assembly and test at deHavilland; anticipated delivery to GE for S/N 104 is in July and S/N 105 is in August.

d. AGE

Fabrication of all AGE has been completed.

e. Test Equipment

Fabrication of all test equipment is complete.

f. Bonded Storage

Plans are being formulated for inventory disposition of the ATS flight equipment in bonded storage at GE.

SECTION 10

NEW TECHNOLOGIES

There are no new technologies to report for the quarter. Efforts to monitor the analytical and developmental areas will continue, and resulting new technologies will be reported in future reports.

SECTION 11

GLOSSARY

The following is a list of abbreviations and definitions for terms used throughout this report:

ADTF	Advanced Damping Test Fixture (used for CPD testing)
ATS-A	Medium Altitude Gravity Gradient Experiment (6000-nautical mile orbit flight)
ATS-D/E	Synchronous Altitude Gravity Gradient Experiment (24-hour orbit flight)
CPD	Combination Passive Damper
Crab Angle	Out-of-orbit angle flight caused by changes in X-rod angle
DME	Dynamic Mission Equivalent (Accelerated Functional Program)
GE-MSD	General Electric Company Missile and Space Division
GGS/ATS	Gravity Gradient System/Applications Technology Satellite
HAC	Hughes Aircraft Company
ITPB	Integrated Test Program Board
Local Vertical	Imaginary line extending from the satellite center of mass to the center of mass of the earth
LOFF	Low Order Force Fixture (used for CPD testing)
MTBF	Mean Time Before Failure
MTTF	Mean Time to Failure
PCU	Power Control Unit
PIR	Program Information Request/Release, GE documentation
SAS	Solar Aspect Sensor
Scissoring	Changing the angle included between the primary booms in a manner that maintains a symmetrical configuration about the satellite yaw axis
STEM	Storable Tubular Extendable Member
Stiction Torque	That amount of torque required to overcome the initial effects of friction
SVA Fixture	Shock and Vibration Attachment Fixture
Thermal Twang	Sudden thermal bending which the booms experience in passing from a region of total eclipse into a region of continuous sunlight or vice versa
TR	Torsional restraint
TVCS	TV Camera Subsystem